Forest Products Journal

1958 YEARBOOK
FPRS Proceedings start P. 91-A

Vol. VIII, No. 10 October, 1958

"We need more trained men in forest products fields" Army Ass't. Secretary Roderick tells FPRS. p. 37-A

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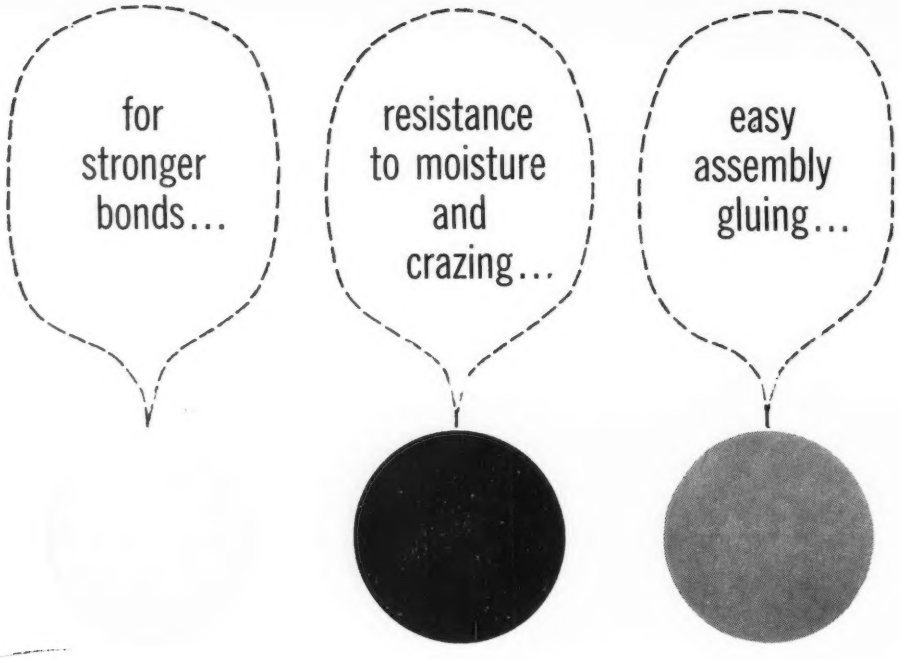

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Feb. 1959: Pacific Northwest Section Meeting, Coos Bay, Ore.

May 21–22, 1959: Joint Eastern Canadian—Northeast Spring Section Meeting, Ottawa, Ontario.

June 28–July 3, 1959: Thirteenth National Meeting, San Francisco, Calif.

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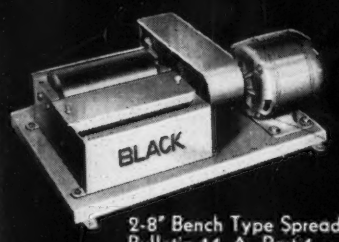

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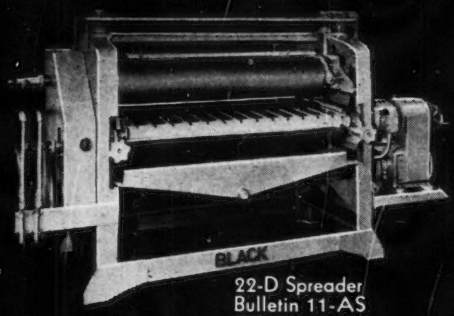

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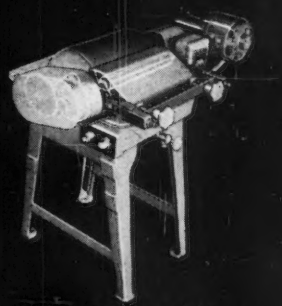
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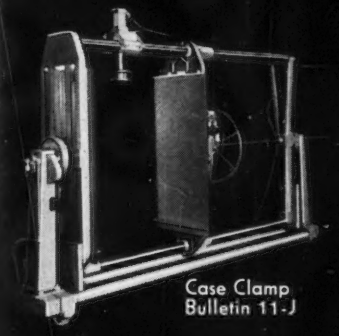
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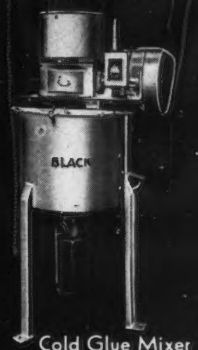

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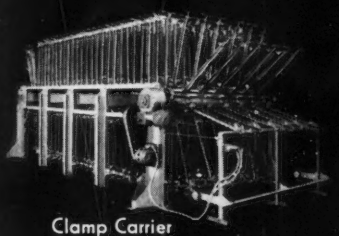
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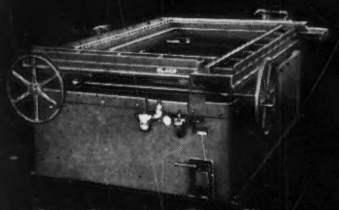
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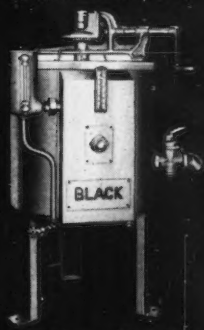

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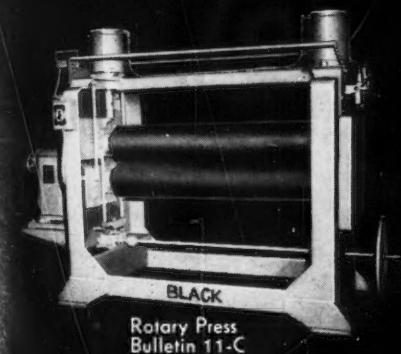

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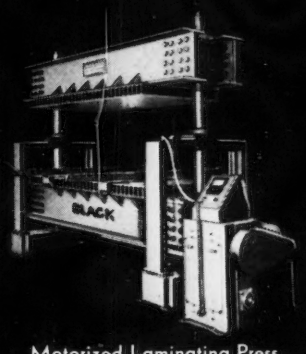

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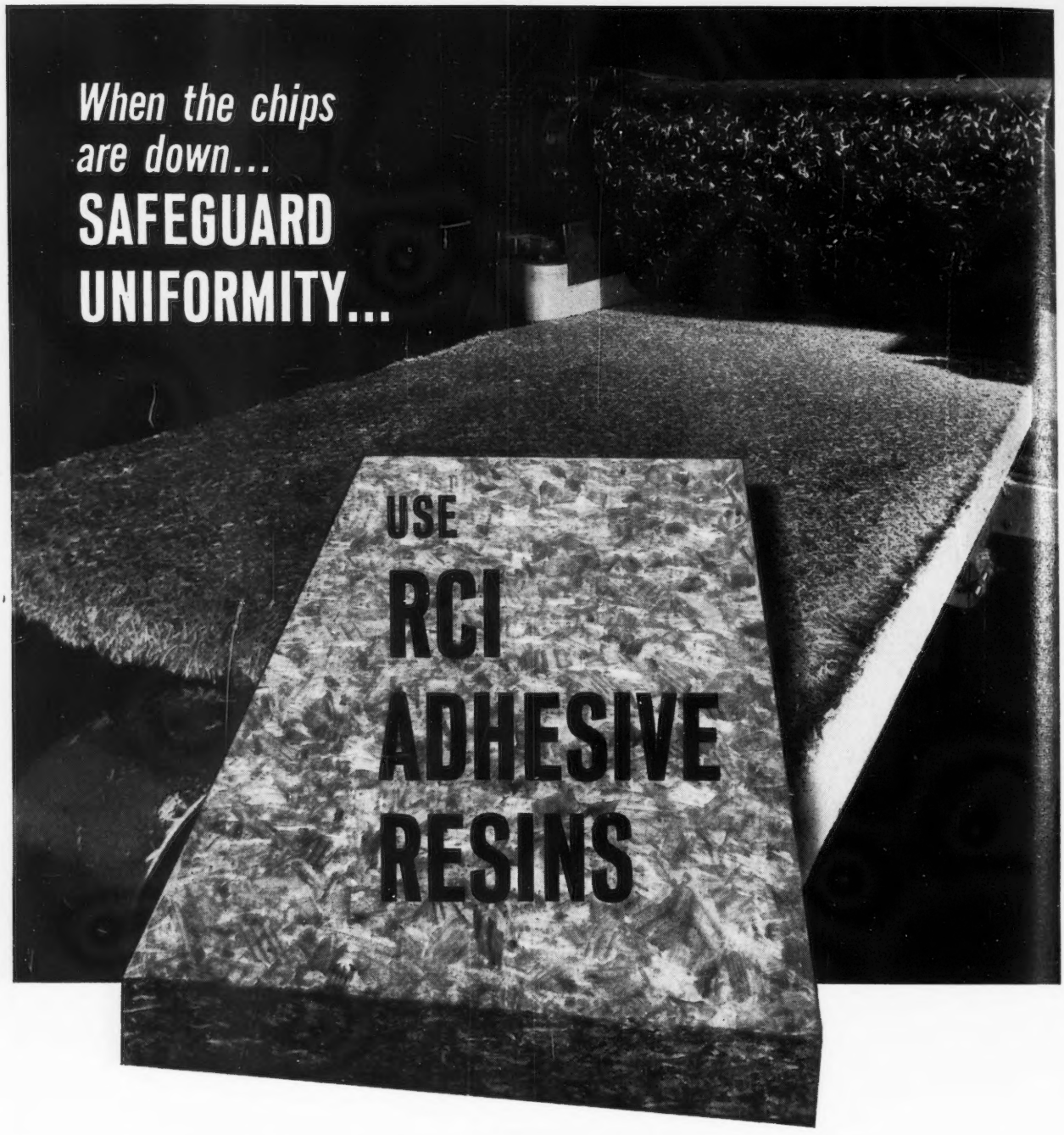

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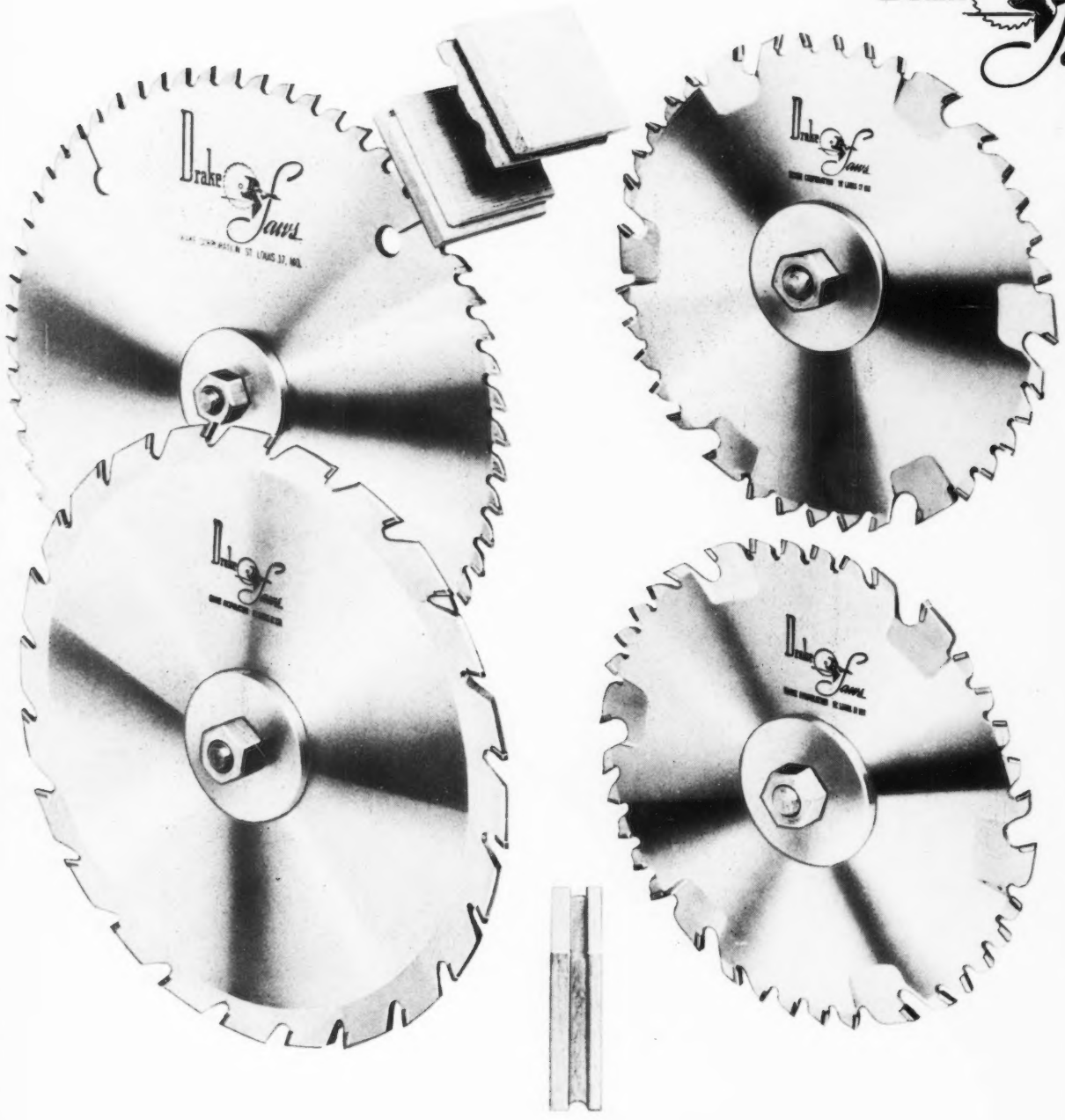

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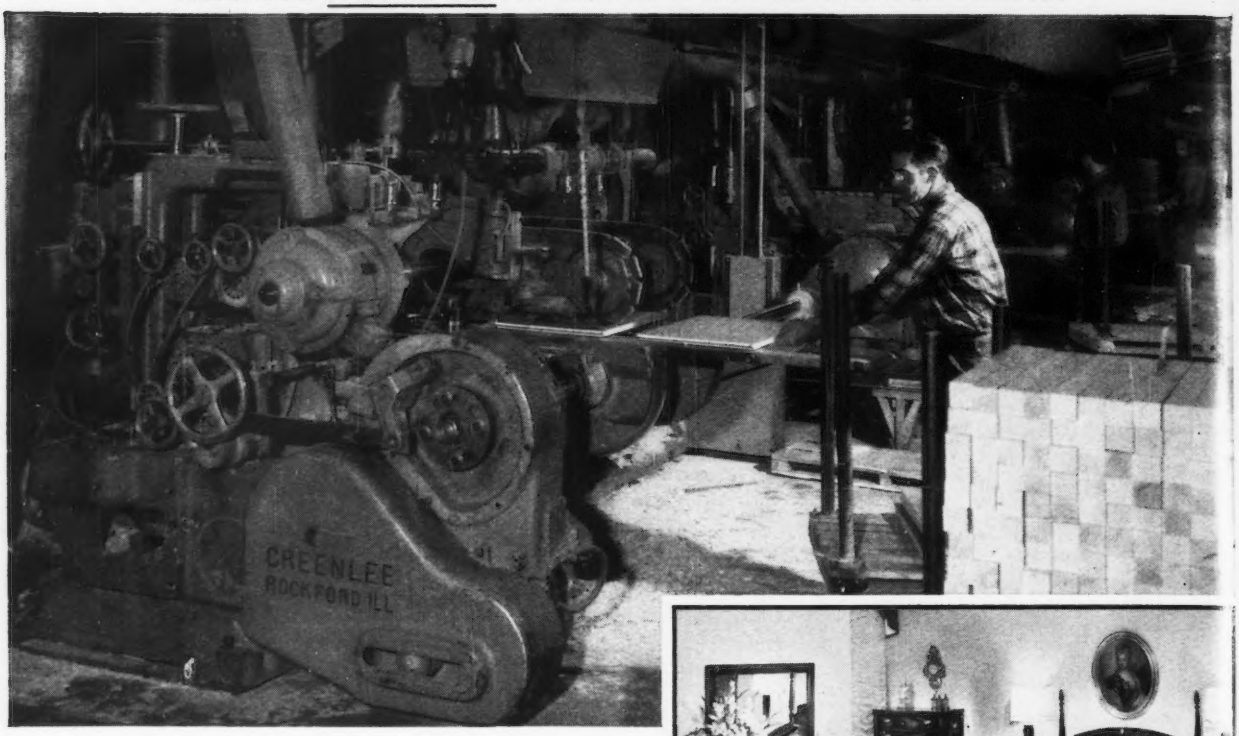

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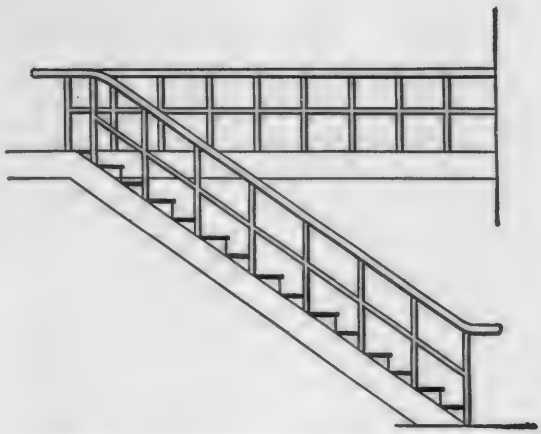

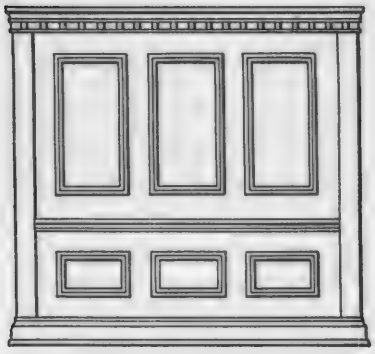

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Meets Federal Specification TT-W-572 and Military Specifications

CHAPMAN CHEMICAL COMPANY
Leading manufacturer of wood preservatives
MEMPHIS 1, TENNESSEE
Minneapolis, San Francisco, Portland, Ore., Charlotte, N. C.

LIC. NO. WATER REPELLENT PRESERVATIVE APPROVED NATL. WOODWORK MFRS. ASSN.

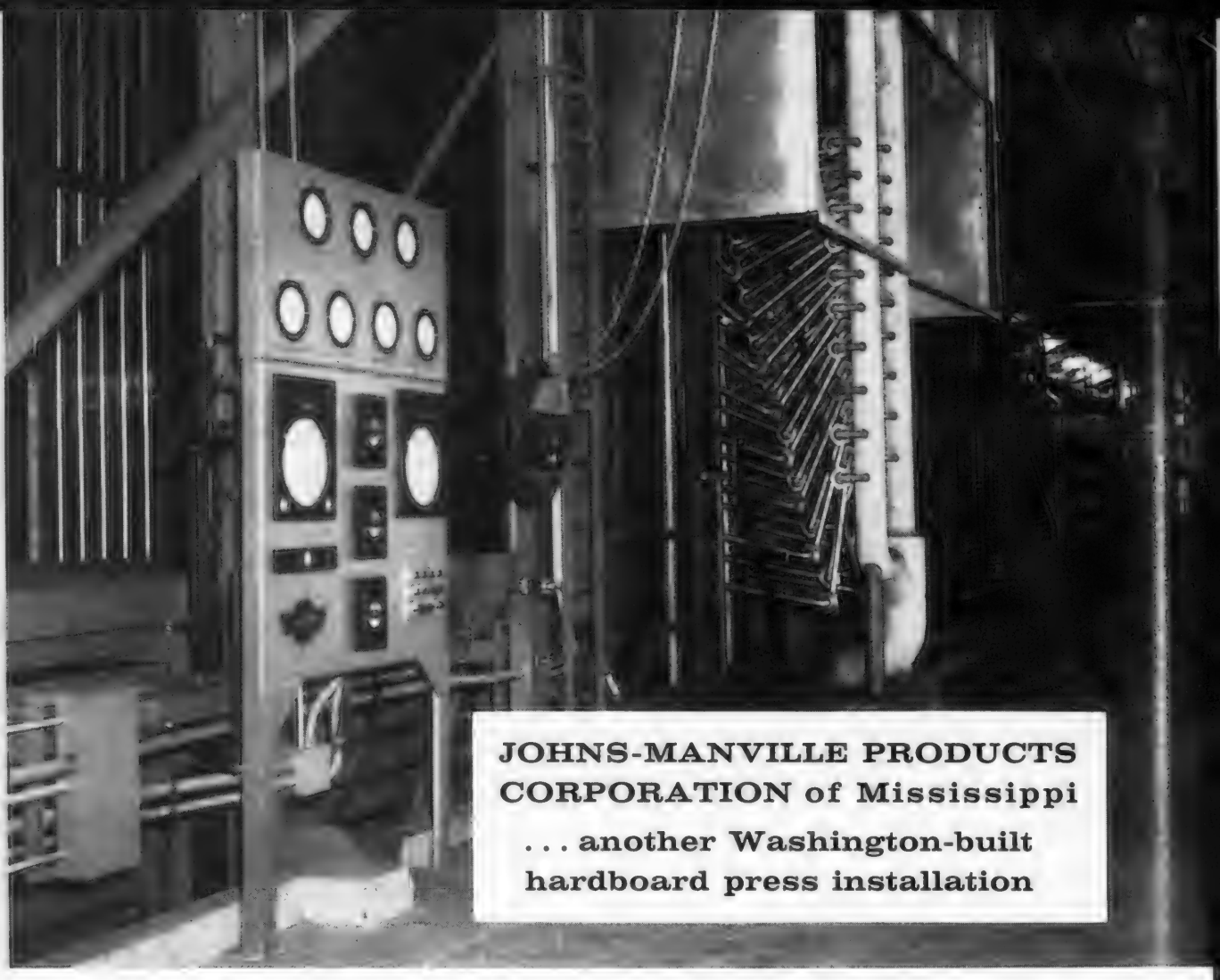
Mail for more information

Chapman Chemical Company
P. O. Box 138, Memphis 1, Tenn.

Please send data on treating millwork with PENTA-WR.

*Name*_____

*Address*_____



JOHNS-MANVILLE PRODUCTS CORPORATION of Mississippi

. . . another Washington-built hardboard press installation

Above is a view of the production line at Natchez with tempering and humidifying equipment in the background, and in the foreground the 3650-ton Washington hot press and controls for automatic operation of the curing stage. Furnished with the press, the control panel in the foreground enables presetting and continuous recording of pressure, temperature and cycle time. The 20-opening press cures twenty mats per load.

Using a new semi-chemical wet process, the new plant can produce finished hardboard panels up to 4′ x 16′ in density ranges from 56 lbs. to 69 lbs. Current production is 65-lb. board.

• • •

Eight other outstanding plants producing particle board, flakeboard and wet and dry process hardboard are featured in the new 16-page brochure "Washington presses and accessory equipment." In-plant photographs, operating data and equipment diagrams provide a valuable round-up of the world-wide production and the industry-wide acceptance of Washington-built press equipment. Your copy is available FREE by writing to Washington Iron Works.

LOCATION: Natchez, Mississippi
PLANT ENGINEERS: Johns-Manville Corporation
PRODUCT: "PanLBoard"® HARDBOARD

Johns-Manville Products Corporation of Mississippi is the newest name in quality hardboard. In the completely modern plant at Natchez, finished hardboard products of several different types roll off the highly automated production line for home and industrial construction. These products include tempered, standard, underlayment and perforated PanLBoard® hardboard in thicknesses from ⅛″ to ¼″.

A Washington 20-opening hot press, one of the largest in the industry, is the key to fast production of uniform, high quality hardboard. Annual capacity is 60 million square feet on a ⅛″ basis.

Washington presses and accessory equipment units are designed and built to meet individual plant and process requirements of board size, thickness and density range, control of pressure, temperature and cycle time, and production rate. For complete information write to Washington Iron Works, 1500 Sixth Avenue South, Seattle 4, Washington.

WASHINGTON presses and accessory equipment

HOT PLATE PRESSES • PULP BALING PRESSES • SPECIAL HYDRAULIC PRESSES • AUTOMATIC PRESS LOADERS AND UNLOADERS • COMPLETE DRY PROCESS HARDBOARD FORMING LINE EQUIPMENT

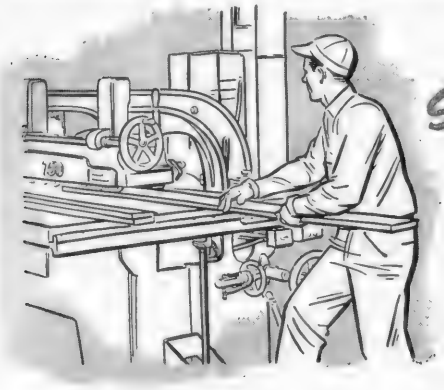
WASHINGTON IRON WORKS

Service

from Montreal to Miami—from Bangor to Burbank, usually in a matter of a few *hours*—rather than *weeks* or *months!* With Diehl machines in thousands of woodworking plants scattered all over the nation, qualified service representatives cover some 120,000 miles per year—*by air* . . . thus assuring fast, dependable service when it is needed *most!*

Service

for Diehl machines no matter when they were built! Diehl has made the finest precision woodworking equipment available since 1909, and can manufacture and *install* parts for any machine during its normal operating life.



Service

is a vital segment of Diehl's far-flung operations, and only Diehl offers such streamlined, dependable service to the woodworking industry! So when you next need a modern, profit-making woodworking machine, see your Exclusive Diehl Representative. He'll show you *dependable* Diehl machinery, backed by *dependable* Diehl service.

THE G. M. DIEHL
MACHINE WORKS, INC.
Wabash,
Indiana

DIEHL *Service* **STANDARD OF COMPARISON IN THE WOODWORKING INDUSTRY**

Lakeland Door Company, Trims Doors and Operating Costs with a Mereen-Johnson No. 600 DOUBLE CUT-OFF SAW

"We've realized big savings since our Mereen-Johnson No. 600 Double Cut-Off Saw was installed three years ago," according to B. A. Kennen, Superintendent of Lakeland Door Co., St. Louis Park, Minn. "Our production capacity is up over previous sawing methods and we now produce over 600 laminated wood doors—trimmed both directions—in an eight hour shift. If necessary, we could produce up to 1,000 finished pieces in the same time and still keep within the required close tolerances."

Quick set-up time is a feature of Mereen-Johnson equipment as provided by a patented snap dog arrangement that allows fast adjustments to be made for varying size doors with a minimum of downtime. Since most of Lakeland's work is "custom-tailored" for individual home contractors, sizes may vary as frequently as every five to ten doors trimmed. This requires fast adjustments to maintain scheduled production. "In a normal shift we may trim as many as 20 different size doors."

While the No. 600 is of medium size, it is well suited for this type of operation and it displays all the quality and workmanship of much larger units. The basic construction of the No. 600 is compact and allows for fast, easy adjustments. Maintenance is practically nothing!

The No. 600 Double Cut-Off Saw is available with trims only—or with tilting cope motors and stationary dado arbor. Special attachments are available as optional equipment.

MEREEN-JOHNSON MACHINE CO.

4401 LYNDALE AVE. NO. • MINNEAPOLIS 12, MINNESOTA

CUT-OFF SAWS	DOUBLE CUT-OFF SAWS	MULTIPLE CUT-OFF SAWS	GANG RIP SAWS
TENONERS	VENEER & PLYWOOD SIZERS & JOINTERS		RESAWS

For complete specifications, write for illustrated Bulletin No. 600-700.

RESIN ADHESIVES by Catalin

. . . set the highest standards for QUALITY, ECONOMY and UNIFORMITY

• UREAS

formula	type	solids	use	for specs
802	liquid	46%	hot & cold press	AN-G-8, CG-496, CS35-49
804	liquid	51%	hot & cold press	AN-G-8, CG-496, CS35-49
813	liquid	65%	hot & cold press	AN-G-8, CG-496, CS35-49
825	liquid	60%	hot & cold press	AN-G-8, CG-496, CS35-49

• MODIFIED UREAS

IMPROVED WATER RESISTANT				
formula	type	solids	use	for specs
8690	liquid	60%	hot & cold press	CG-496, CS35-49
CRAZE RESISTANT TYPE				
8666	liquid	60%	intermediate & cold press	CG-496, CS35-49

• RESORCINOLS

formula	type	solids	use	for specs
726	liquid	57%	hot & cold press	MIL-A-397B
731	liquid	55%	hot & cold press	MIL-A-397B
736	liquid	56%	hot & cold press	MIL-A-397B

• PHENOLICS

formula	type	solids	description
9068	liquid	66%	Fast-curing water-soluble resin for particle board.
9297	powder	—	Fast-curing resin for increased flexural strength and moisture resistance, used for molded shapes of wood flour and particle board.

Since the introduction of resin adhesives, a little more than a quarter-century ago, Catalin's ability to develop and deliver the most modern types of resin with absolute uniformity . . . batch after batch . . . month after month . . . has won the highest regard of woodworking production personnel.

The versatile adhesives listed here, together with Catalin-developed accelerators, because they establish superlative levels of dependability, quality and economy, have found wide acceptance for both hot and cold press woodworking operations and products. Catalin field representatives are qualified to assist you in adapting these formulations to your specific requirements.

Fast deliveries from three strategically located plants in the East, Midwest and South — Fords, N. J., Calumet City, Ill., and Thomasville, N. C. — are a feature of Catalin's unsurpassed service.

Write for your free copy of "Catalin Adhesives," which describes all the types Catalin produces and contains a special section of practical hints on the successful use of urea resin adhesives.

CATALIN CORPORATION OF AMERICA
ONE PARK AVENUE • NEW YORK 16, N. Y.
— Plants —
Fords, N. J. • Calumet City, Ill. • Thomasville, N. C.

BRATTLEBORO KILN DRYING & MILLING COMPANY has stepped up to **STANDARD**—Irwin Elkins, general manager of this Brattleboro, Vermont firm, says: "We purchased eight Standard kilns in 1954, and two more in 1956 (latter two shown above). We're obviously very satisfied."

Step up to STANDARD

for uniformly-dried lumber at lowest possible cost

● For any type of new kiln installation, or for remodeling of old natural draft kilns, call on Standard—manufacturers and designers of today's finest internal-fan kilns—to solve *your* drying requirements *best*. Write for information, and a free copy of our complete Equipment Catalog and Prefab Kiln Brochure.

CHESTER B. STEM has stepped up to **STANDARD**—C. B. Stem, president, writes: "We are glad to report we have had very satisfactory service from our four Standard package kilns. We can truthfully say we have had no difficulties whatsoever and we have received no complaints from any of our customers concerning lumber dried in these kilns. That in itself should tell the whole story."

STANDARD FURNITURE COMPANY has stepped up to **STANDARD**—This firm has five Standard prefabricated kilns installed at its Herkimer, N. Y. plant.

REMEMBER,

quality control starts with your dry kiln. Make sure it's the finest—make sure it's Standard.

GUNLOCKE CHAIR has stepped up to **STANDARD**—Located at Wayland, N.Y., this installation consists of eight prefabricated kilns. Mr. Howard Gunlocke says: "If I had to do it over, they still would be Standard prefab kilns—the only way to build kilns!"

Manufacturers of Internal Fan Kilns

STANDARD
Engineers and Manufacturers Since 1887
DRY KILN COMPANY

P. O. BOX 5708 • INDIANAPOLIS 21, INDIANA

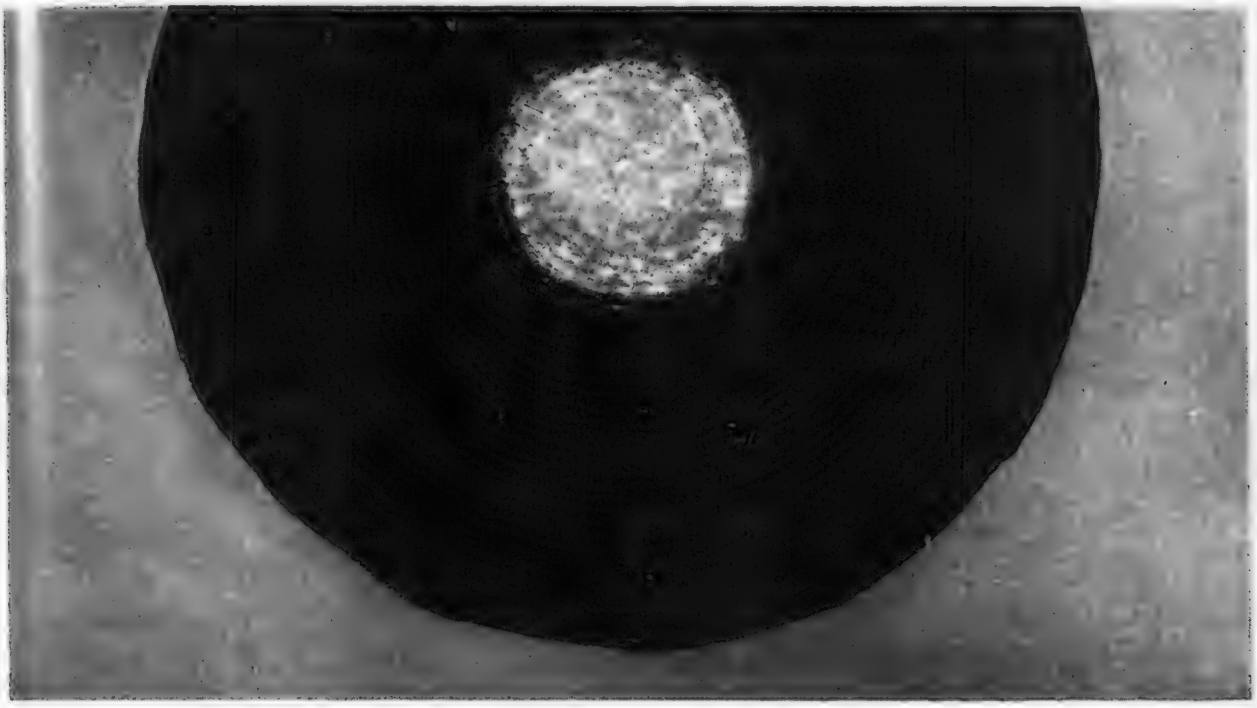
STANDARD HAS THEM ALL

- Prefabricated Kilns
- Package Loaded Kilns
- Remodeled Kilns

OTHER QUALITY STANDARD PRODUCTS

Lumber Stackers • Dry Kiln Doors • Power Transfer Cars • Lumber Lifts • Kiln Trucks • Moisture Registers

Why it pays to PRESSURE-TREAT with CREOSOTE



Depth of penetration can be visibly checked!

With pressure-creosoting there is no guesswork; no involved analyses are necessary to make sure of preservative penetration depth. You can actually *see* the creosote in any cross-section!

OTHER IMPORTANT ADVANTAGES:

Chemical stability: Creosote does not decompose or react chemically with soil-water to become soluble under any service conditions — even in piling that has been submerged for many years.

Longest proved protection: Creosote is the *only* time-proved preservative. There are numerous cases of pressured-creosoted wood that has been in service *well over 50 years*!

Multiple toxicity: Because creosote consists of many toxic components, wood-destroying insects and fungi and marine borers cannot build up an immunity.

Retards checking and brooming: Creosote remains in the wood, fights moisture, helps prevent checking and brooming.

Resists destruction by grass and brush fires: Whereas certain preservatives using light petroleum solvents can actually be fire hazards, creosote protects wood from most small fires.

It's available anywhere—fast: Qualified pressure-creosoting plants are located in *every* section of the United States.

Dollar for dollar your best buy is Creosote—the only time-proved preservative! Add up all of creosote's advantages and it's easy to see that today — as always — pressure-treatment with Coal-Tar Creosote gives *more* protection per dollar than any other type of preservative available. For more detailed information, write for our 16-page booklet. In Canada: Allied Chemical Canada, Ltd., 1450 City Councillors Street, Montreal.

PLASTICS AND COAL CHEMICALS DIVISION
40 Rector Street, New York 6, N. Y.

Allied Chemical

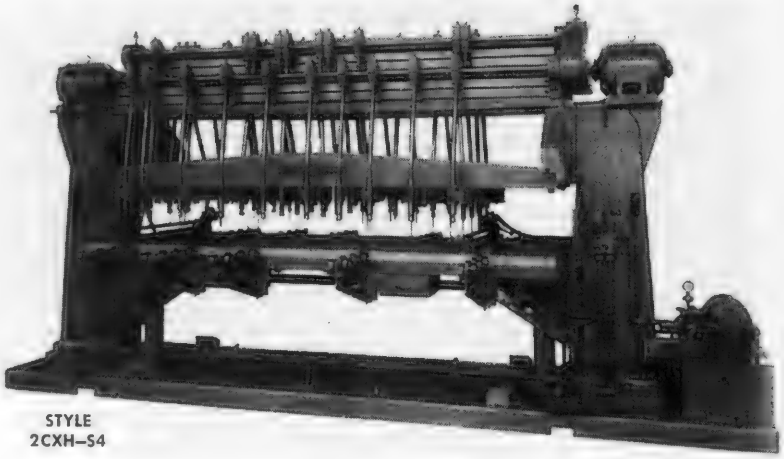
2 NEW MACHINES
solve unusual wood boring requirements

ROOT "2CXH–S4" MULTIPLE BORER
opens new phase in large area boring

ROOT "CCH" MULTIPLE BORER
3 machines in one—answers production problem of boring stock having wide variances in length

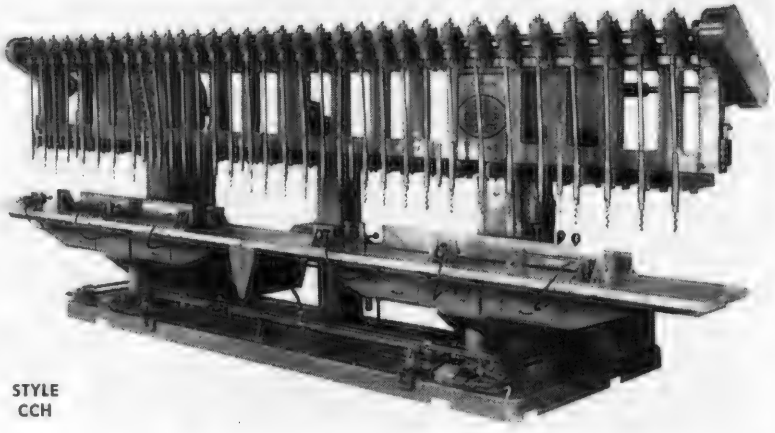
This special 2CXH–S4 Multiple Borer can bore up to 40 holes or more simultaneously in panels up to 10 ft. by 4 ft. Its design offers many engineering "firsts" that make it highly efficient in production boring of large-area work.

It is equipped with adjustable alignment guides and clamping devices, and special in-feed and outfeed roller brackets. Its table is hydraulically operated, with special limit switches that require positive positioning of the work before allowing the boring stroke to start. With slight changes in design this machine can handle panels of any practicable size.



STYLE
2CXH–S4

This large CCH Multiple Borer, with hydraulic feed, was built to bore boards and members used in refrigeration cars, some stock being 20′ long, other stock less than 10′. To handle all stock efficiently this machine was designed with a divided table. With the table operating as a single unit, all controls and drives work as one large machine for boring the long stock. Then by simple adjustments the machine becomes two smaller independent borers for handling the short stock. It has 33 universally adjustable spindles for in-line or out-of-line boring over a maximum area of 21′–4¼″ by 12″ cross-line, also many other features.



STYLE
CCH

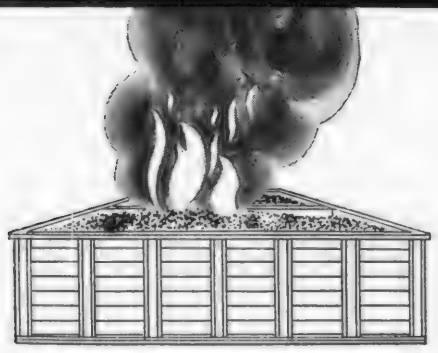
Write today for complete details on these and other large and unique wood boring machines by Root, also for full information on the standard line of Root production machinery for the woodworking industry—no obligation.

B. M. ROOT CO.
YORK — PENNA.

Factory Mutual Laboratories, Norwood, Mass.

NON-COM

A NEW CHEMICAL DEVELOPED BY KOPPERS MAKES WOOD NON-COMBUSTIBLE



After years of research, Koppers announces NON-COM, a new and highly effective chemical that imparts superior fire resistance to wood. Wood pressure-impregnated with NON-COM salts will not ignite or support combustion. And although NON-COM pressure-treated material will char slowly where exposed to flame, it confines the fire to the point of origin by checking flame spread.

Tests conducted by Factory Mutual Laboratories indicate that heat contribution from NON-COM branded materials is not more than that from Class I metal roof deck construction for a thirty minute period.

NON-COM pressure-treated materials have been tested and listed by Underwriters' Laboratories and recognized by many state rating bureaus. Also, it meets Federal specifications for fire retardants. So effective are NON-COM materials as a fire resistant—fire insurance premiums are more than cut in half where NON-COM treated materials are used.

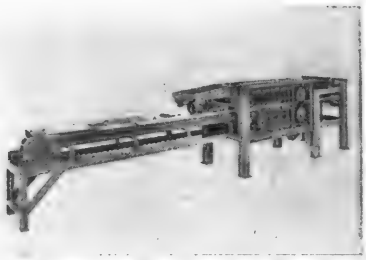
The perfection of NON-COM fire-resistant wood is another milestone in Koppers continuing research to make wood serve industry better.

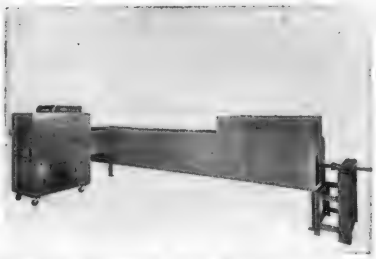
KOPPERS COMPANY, INC. G-23

KOPPERS®

PRESSURE-TREATED WOOD

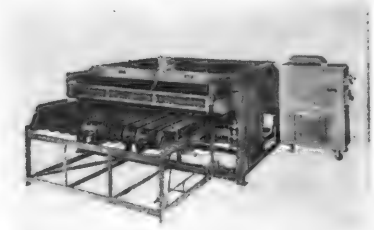
Wood Preserving Division, Pittsburgh 19, Pennsylvania



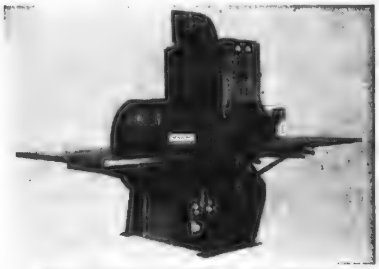


Mann-Russell Continuous High Speed Finger Joint Gluer. Left, Assembly-Drive-First Retarder. Right, Mann-Russell Special Design Heat Retention Electrode and Second Retarder with 20 kw Output Electronic Generator.

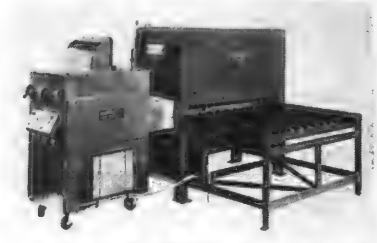
Mann-Russell Continuous Electronic Lumber Edge Gluer



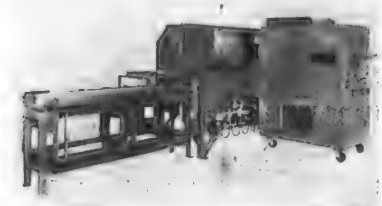
Continuous Electronic Veneer Edge Gluer



Mann-Russell-Globe Electronic Plywood Panel Patcher



Mann-Russell Electronic Scarf Gluing Press



Mann-Russell Electronic Face Gluer for production of roof decking, laminated timbers, 4x4's, 4x6's and 4x8's from 1" and 2" material; to any specified length by batch method.

what's your glue line?

If you edge-glue lumber, veneer, do panel repair patching, scarf plywood . . . laminate structural beams, roof decking or other structural members . . . do ANY type of gluing with soft or hard woods, Mann-Russell can

Speed Your Production . . . Cut Costs

No matter what **your** glue-line problems may be, Mann-Russell can offer a solution that will increase production, reduce overhead, provide greater utilization of shorts and waste stock.

Mann-Russell equipment is engineered, and single responsibility assumed, for the specific job . . . installed and serviced by factory engineers. Why not glue the **modern** way — electronically? Write, wire, or call . . .

Mann-Russell Electronics
(NORTHWEST SYNDICATE, INC.)

PLANT: South 23rd & Pacific Avenue
Tacoma 2, Washington
FUlton 3-1593

Why Curtis bonds particle wood with DUREZ...

strength, clarity, ease of use of DUREZ phenolic resins help make fine kitchens

CURTIS KITCHENS, in natural birch or decorated with a choice of colors, are designed and built with "the 53 features women want most"...and not the least of these advantages are achieved with Durez-bonded "Prespine".

BY PRODUCING "PRESPINE" to its own specifications from wood particles, Curtis assures a quality board from material that would otherwise be lost. It is used for sides, backs, and drawer bottoms. It is free from checking or delamination, and provides an excellent base for decorative finishes.

NOTABLE ADVANTAGES of Durez phenolic resin for Curtis are its strength and the absence of discoloration which permits a close match with natural wood. Durez has excellent flow properties. Its uniformity simplifies control of product characteristics—density, hardness, freedom from splitting or chipping.

LOW-PERCENTAGE MIXTURES of Durez resins and ground wood have many inviting commercial possibilities in the fields of particle board, core stock, and compression-molded wood products. If you are interested in the profitability of reconstructed wood in your operations, we can help you. Our long experience in resin research and development is at your service.

DUREZ®

Phenolic Resins that Fit the Job

DUREZ PLASTICS DIVISION
HOOKER CHEMICAL CORPORATION
3915 WALCK ROAD, NORTH TONAWANDA, N. Y.

HOOKER CHEMICALS PLASTICS

This Moore Stacker Pays Off for Cotton-Hanlon

Have the Moore Engineer make free plant survey, and learn how YOU can save with a Moore Stacker or Unstacker.

MAKE MOORE YOUR HEADQUARTERS FOR

- Stackers & Unstackers
- Breakdown & Loader Hoists
- Lifts (Cable & Hydraulic)
  - Dry Kilns
  - Cabinet Dryers
  - Prefab Kiln Buildings
- Belt Conveyors (All Types)
- Rolls (Power & Gravity)
- Haul-Up Chains
  - Electric Swedes
  - Turntables
  - Transfer Cars
- Transfer Chains
- Dry Kiln Instruments
- Special Design Machinery

Read what Howard Hanlon, president of Cotton–Hanlon, Inc., Odessa, N. Y., has to say about his new Moore Chain-Arm Stacker:

> ***"Our labor costs have been reduced about 60% and stacking quality immensely improved. As far as we are concerned, the stacker was a matter of survival."***

Cotton–Hanlon records show on one 8-hour day recently, the Moore Stacker enabled a 4½ man crew (4 men half the time, and five the other half) to stack 60,000 feet of Northern hardwoods 4/4 up to 16/4 thick.

NOW IS THE TIME to learn how a Moore Stacker, Drying or Unstacker System can increase your profits. Write today for information.

CROSS-CIRCULATION DRYERS — SINCE 1879 — MOORE DRY KILNS — THE WORLD OVER

MOORE DRY KILN COMPANY

Oldest and Largest Manufacturers of Dry Kilns and Veneer Dryers

JACKSONVILLE FLORIDA | BRAMPTON, ONT. CANADA | VANCOUVER, B. C. CANADA | NORTH PORTLAND OREGON

Serving the Industry Since 1852

It's Revolutionary!
A-484M DIAGONAL PLANER and MATCHER

Upgrading of all stock, with astonishing improvement in finish on the lower grades now made possible with this revolutionary DIAGONAL PLANER and MATCHER.

DISTINCTIVE FEATURES

- ★ Elimination of sniped ends.
- ★ Smoother finish around knots and cross grain, with less tendency to loosen knots.
- ★ Continuous support of stock on bed plate before and after cut on bottom head.
- ★ Less lead required in guide as angle cutterhead serves to hold stock against the guide fence, preventing side friction, feed roll wear and edge sniping.
- ★ Less power consumption in feeding stock.
- ★ All operating adjustments can be made from the front or working side of machine.
- ★ Wide face helical gears for feed works, assuring continuous tooth mesh and quieter operation.
- ★ Independent quick green stock lift for first bottom feed-in rolls.
- ★ Bottom head cylinder can be pulled out for changing knives without disassembling motor.
- ★ Individual ball bearing housings for all cutting units.
- ★ All ball and roller bearings housed in dustproof housings. Grease lubricants for roll bearings. Regulated wick oil feeders used on all cutting units. Forced feed lubrication for feed gears.

Write Today for the A484-M Booklet

S. A. WOODS MACHINE CO.
27 DAMRELL STREET
BOSTON 27, MASS.

GLUING VENEERS for curved panels prior to hot pressing. Core is poplar; surface veneer is walnut, mahogany, cherry or oak—all dried to 6% moisture content.

VENEER PACK, up to 13 ply, goes into forms in electronically heated press which exerts 15[illegible] to 175 p.s.i., cures panels in 3 to 5 minutes.

WORKER REMOVES formed panel as fresh pack goes in from other side. Press stays open only 30 to 45 seconds. Three men are needed for maximum production.

FORMS, made in firm's shop, are laminated fir plywood covered with 1/32 in. aluminum and cost from $250 to $500 each. Metal bands at ends transmit heat to pack. Sheet of 1/20 in. hardboard is used as liner under metal sheets to help provide cushioning, uniform pressing surface.

Electronic Hot Press Averages Curved Form Per Minute; Uses Shop-Made, Low-Cost Forms

ELECTRONIC PRESSING turns out an average of more than one curved or serpentine panel each minute at Kent-Coffey Mfg. Co., Lenoir, N. C. "The electronic hot press system produces curved forms more economically, rapidly and accurately than the band sawing system we formerly used," says Harry E. Beatty, plant superintendent.

"The press produces up to three curved forms at once in a press cycle that ranges from 3 to 5 minutes" he says. "Our daily production of curved forms ranges from 2,700 sq. ft. to 3,000 sq. ft."

Ralph H. Martin, glue and veneer room foreman, points out: "Installation of the electronic hot press system meant greater utilization of our veneer room. Moreover, it eliminated a great deal of work from the rough mill which formerly cut the stock used for the laminated blocks for band-sawing of curved panels. In that operation, waste often ran as high as 70%. Thus we have saved time and freed highly paid personnel for other skilled work.

We also find there are far fewer rejects than occurred under the old system during sanding operations and our electronically cured panels are more uniform and accurate."

The press described here is a Lodge & Shipley "Columbia" High-Frequency Press specially designed for the production of better curved panels . . . chair seats and backs, case goods, cabinets, fronts . . . at low cost. Because cure time is measured in minutes, you get high production from a single set of forms. Floor space formerly used for curing storage can be used for profitable production. Small lot production is practical.

The Columbia High-Frequency Press gives double versatility; it is quickly switched over to conventional cold press work. High-Frequency equipment and shielding meets all FCC requirements. For complete details, request Bulletin No. HP-17 from:

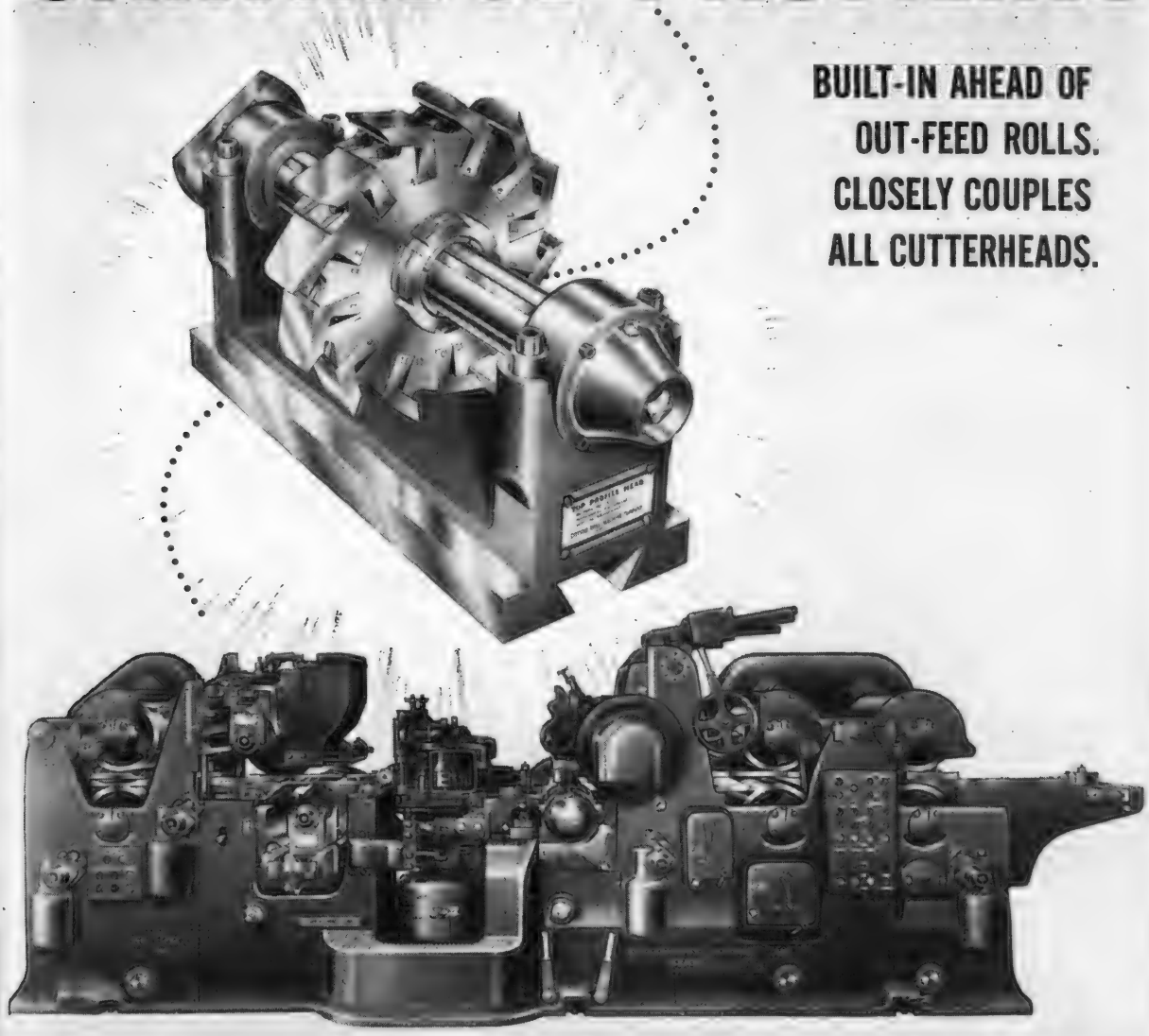
THE Lodge & Shipley COMPANY

3063 Colerain Ave., Cincinnati 25, Ohio

COLUMBIA PRESSES for the wood and wood products industry

Photos and data courtesy WOOD AND WOOD PRODUCTS

*CARTRIDGE PROFILING



BUILT-IN AHEAD OF OUT-FEED ROLLS. CLOSELY COUPLES ALL CUTTERHEADS.

An original cost reducing feature of Stetson-Ross Planer-Matchers for over 45 years

*Pre-set "cartridge" profile units built-in ahead of outfeed rolls give you highest quality millwork, and instantaneous pattern change through the use of spare "cartridge units." These are fundamentals of good machine design, developed and perfected by Stetson-Ross.

Touchup jointing of profile "Cartridges" on the machine, spring-loaded sectional pressure plates, on top profiler and numerous optional profile features have been available for many years on our machines.

For tomorrow's planing mill profits today, see Stetson-Ross!

STETSON–ROSS
MACHINE COMPANY INC
SEATTLE 4, WASHINGTON

EXPORT DIVISION
301 CLAY STREET, SAN FRANCISCO, CALIFORNIA

AND NOW *Another* COVETED

Certificate of Merit

awarded at the 1958 A.I.A. Convention for the STRONGHOLD LINE® Sample Board

These pieces won Certificates of Merit in NAHB-Producers' Council 1957 *Ideas for Homebuilders* Contest. "Good descriptive information . . . Excellent guide and presented in a clear, concise manner," the judges commented.

LET'S NAIL DOWN SOME FACTS
about
• greater holding power
• lower cost per piece
• better, stronger fastening
• savings in time and labor
• savings in fastening cost
• freedom from repairs

1958
Award-Winning
NAIL SAMPLE BOARD

Handy to stand on desk or drawing table, this 12" x 18" easel-back display carries actual samples of 50 improved fastenings that hold tighter, longer—enable you to use new cost saving techniques and materials.

Award-Winning

Literature — plus a sample board and technical bulletins—yours for the asking!

STRONGHOLD® Annular Thread and SCREW-TITE® Spiral Thread Nails have revolutionized construction methods. Scientifically engineered threads "lock" with the wood fibres; the nails hold tight, actually *gain holding power after driving*. They make house frames up to 5.7 times as strong—keep wood floors and underlayment smooth and squeak-free—virtually eliminate "popping" nail heads that mar beautiful gypsum board drywall—hold shingles secure in winds up to three times hurricane force. They permit the use of fewer nails, shorter nails, slimmer nails; with important savings in time, labor, materials. Many architects are finding this award-winning literature and the sample board helpful. They are yours for the asking, along with an up-to-date binder of bulletins reporting data and findings resulting from the continuing program of research and testing carried on at Wood Research Laboratory, Virginia Polytechnic Institute.

Practically all of the authoritative data available on the holding power of threaded nails is the result of research reported in these VPI Bulletins.

"Drives Like A Nail...Holds Like A Screw"

INDEPENDENT NAIL & PACKING CO.

Pioneer Developers and Largest Manufacturers of Threaded Nails

BRIDGEWATER, MASSACHUSETTS, U.S.A.

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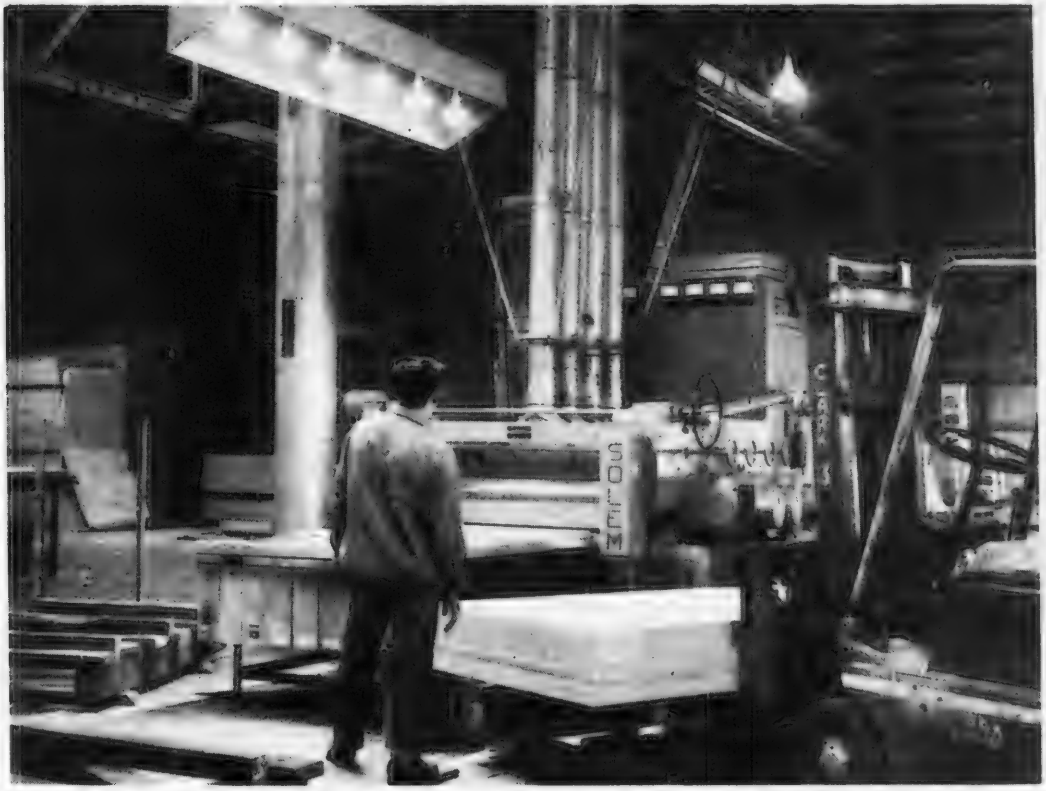
SOLEM DOUBLE-DECK SANDERS BRING PARTICLE BOARD TO EXACT THICKNESS



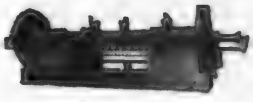
Outfeed end of Solem Eight-Drum Double-Deck Sander, processing particle board at the Pacqua Inc., Division of Pacific Plywood Co., Dillard, Oregon.

SOLEM'S NEW PLANT IN ROCKFORD

Solem's new plant in Rockford, Illinois is conceived and planned with the idea of bringing Solem Machine Company and the Merritt–Solem Division together under one roof as soon as possible, to more closely integrate and expedite the entire operation. This large plant will make it possible for us to pass still greater benefits along to our customers and provide them with still better service.

ONE PASS THROUGH THE SOLEM

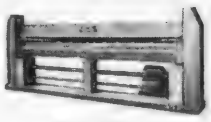
One pass through the Solem Double-Deck Sander is all it takes to bring particle board to exact thickness required and smooth both sides at the same time . . . that's real production. No duplication in handling . . . the rough board goes through the Solem and comes out finished, directly to the waiting lift truck as shown above, to be transported to railroad car or shipping room.



Veneer Lathes

Whether You Make Particle Board Or Plywood

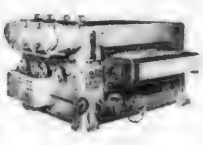
You'll find a ready need for the Solem Double-Deck Drum Sander and its huge work capacity. You can shift from Plywood to Particle Board quickly if your production requires it . . . it's all the same to the Solem. There are no drum marks; drums oscillate 236 times per minute. Micromatic Dial for quick setting.



Veneer Clippers

Lathes, Clippers, Jointers, Presses

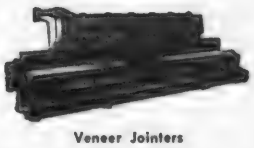
Merritt–Solem Division in Lockport, New York, makes other machines needed in veneer and plywood production, shown on this page.



Solem Endless-Bed Drum Sanders

Hot Plate Presses

Write Today For More Information



Veneer Jointers

SOLEM MACHINE COMPANY

ROCKFORD ILLINOIS

NOW IS THE TIME TO ACT TO PREVENT WINTER'S DRY AIR LOSSES

1.
RELATIVE HUMIDITY 60%. Assume the windows are open in your plant. It's a warm day and relative humidity is 60%. A cubic foot of wood in your plant holds nearly 3½ pints of water. Now see 2.

2.
RELATIVE HUMIDITY 10%. A cold snap drops outdoor temperature to 20°F, 75 RH. Heat your plant to 75°F and the wood losses nearly 3 pints of water to the dry indoor air.

3.
QUICK DROP CAUSES THIS! The wood shrinks as it loses moisture, setting up stresses that cause cracking, checking, warping—(losses that, each year, will more than pay for Armstrong Steam Humidifiers.)

Install ARMSTRONG STEAM HUMIDIFIERS ...let them pay for themselves through savings this year

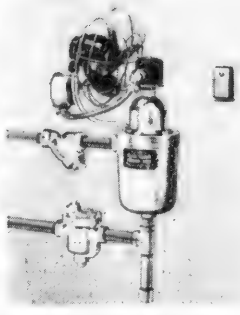
The photos above tell the story, the results of which you will probably see repeated in your plant this winter—unless you humidify. Install humidifiers *now,* and you can prevent *any* dry air loss.

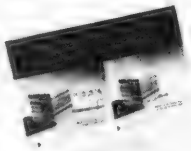
Armstrong Steam Humidifiers give you many advantages. They discharge steam directly into the room. Since steam is distilled water in the form of a gas, there is no mineral or moisture "fall-out".

Installation is easy—similar to unit heaters. Controlled by sensitive humidistats, Armstrong Steam Humidifiers give accuracy within 2 to 4% of setting. The simple, sturdy design makes for negligible maintenance. They work for pennies a day, and commonly pay for themselves in one season.

Armstrong Steam Humidifiers are so proved in service that they are *unconditionally guaranteed* to satisfy—on a money-back basis.

AUTOMATIC •
ACCURATE •
TROUBLE-FREE •
LOW COST •
HIGH CAPACITY •
CLEAN •
GUARANTEED •





BULLETIN GIVES THE FACTS ON HUMIDIFICATION IN WOODWORKING

Bulletin 505 tells: Importance of humidification in modern woodworking . . . how relative humidity affects woodworking . . . advantages of Armstrong steam humidification . . . benefits obtained by present woodworking users. To get your copy, call your Armstrong Factory Representative, or send the handy coupon today to:

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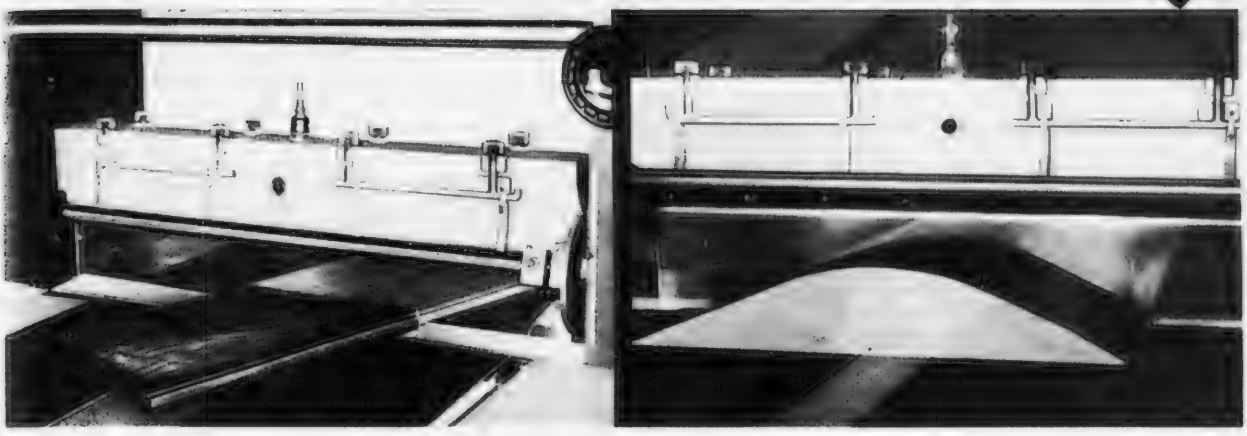
Name_____

Attach to company letterhead and mail.

For FLAT or SHAPED PRODUCTS



Revolutionizing Industrial Finishing—

THE STEINEMANN COATER

Pressure Curtain Application

Manufactured By
George Koch Sons, Inc.,
Evansville, Ind.

The Steinemann Coater assures a finish of precision uniformity down to .5 mils thickness through application of finishing material by a pressure curtain. Speeds up to 400 feet per minute may be maintained.

With the Steinemann Coater, waste is completely eliminated. There's no mist . . . unused finishing material is automatically returned to a reservoir for recirculation.

The Steinemann Coater handles products of nearly any shape, size or thickness. Machines come in six standard widths 12″ to 75″. Feed and exit tables are available in a range of sizes.

Units with two pressure applicating heads are ideal for finishing with two-component polyesters.

The Steinemann Coater can be operated by unskilled labor. Maintenance and wear are at a minimum.

Steinemann Coaters Apply These and Other Finishes:

Plastics—polyesters
Paints
Urea-alkyds
Lacquers
Varnish
Shellac
Epoxy-resin
Resin adhesives
Nitro-cellulose synthetics
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Simplicity of Design
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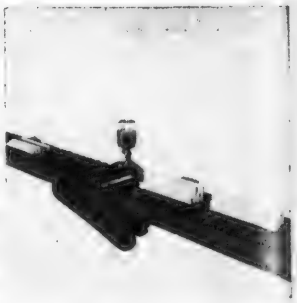
THE TAYLOR PANEL-FLO . . . Unmatched for output! Capable of production up to 4,000 ft. of Edge Gluing per hour.

THE TAYLOR PANEL-MINT . . . Unequaled for One-Man Production! Hydraulic press automatically loaded, timed and unloaded, combined with automatic reversing spreader, permits low cost gluing by one-man alone.

THE TAYLOR AUTOMATIC PANEL SIZING SAW . . . Eliminates labor and lumber waste in sizing panels to width automatically, direct from the Panel-Flo, thus achieving the ultimate in savings.

THE TAYLOR AUTOMATIC CONVEYOR TYPE GLUE APPLICATOR . . . Uniformly coats large quantities of prepared stock automatically, without skips. Its versatility is evident in the several modified designs to do specialized coating of laminated or edge glued stock.



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Edge Gluing Specialists Since 1900

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FPRS NEWS-DIGEST

Volume VIII | OCTOBER, 1958 | Number 10

FPRS Lumber Mfg. Division Holds Meeting at Eau Claire

The Lumber Manufacturing Division held a breakfast meeting on Oct. 3, at Eau Claire, Wis., during the Upper Mississippi Valley Section Fall Meeting, according to M. H. Mater, Division Chairman. Thirty-five Division members located in the region were invited to attend. The principal purpose was to select tentative topics for presentation at the 1959 National Meeting.

One of the Society's most active groups, the Division has recently prepared a report on research needed in the field of Lumber Manufacturing. During the June National Meeting of the Society, the Division established a clearing-house committee to disseminate the information gathered in the report. (For more details see page 00–0)

Five Sections Move Toward Adoption of Uniform By-Laws

Progress on the adoption of uniform by-laws is being steadily made by the FPRS 14 Sections, D. K. Saunders, National Chairman of the By-Laws committee, reported recently. Since the 1958 National Meeting, several of the Sections have started work on their by-laws, he said.

Two Sections, the Great Lakes and Upper Mississippi Valley, voted on the adoption of new by-laws at the end of September and the beginning of October, respectively, according to the National Executive Office.

The Executive Boards of the Eastern Canadian and Midwest Sections are considering trial drafts to submit to their membership, and a special committee on by-laws has been appointed in the Northeast Section.

Sections already having by-laws that conform to Executive Board requirement are: Pacific Southwest, Mid-South, Northern California, Carolinas–Chesapeake, Rocky Mountain, Inland Empire, and Florida–Georgia–Alabama Sections.

14 Sections to Help Distribute NLMA-FPRS Career Booklet

Industry–Education Committees within each of the 14 Sections of the Society are being formed for the purpose of aiding in distribution of the NLMA–FPRS career booklet, F. J. Rovsek, Executive Secretary, reports.

The suggestion to establish these committees arose out of the special meetings of Division and Section officers during the June National Meeting of the Society. Dr. J. S. Bethel, chairman of the Industry–Education Committee, has requested that the National Office proceed with the establishment of these groups.

Purpose of Booklet

Designed to attract high school students to the forest products industries, the finished draft is called "Opportunities Unlimited". The booklet is expected to be ready during the annual meeting of the National Lumber Manufacturers Assoc., in Nov., at Washington, D. C. The original draft of the booklet was written by Dr. F. F. Wangaard, Yale, under the auspices of the FPRS Industry—Education Division.

The Industry–Education Division first proposed publication of the booklet to NLMA in November of 1955. In 1957, the lumber group provided substantial funds in the 1958 budget for preparation of this publication. The pamphlet will be distributed to high schools throughout the country and will be undertaken in varying ways in different areas.

Members of the NLMA Committee on Education are R. H. Berry, Scott Lumber Co., Chairman; L. J. Carr, L. J. Carr & Co.; N. B. Giustina, Giustina Bros. Lumber Co.; H. B. McKean, Potlatch Forests; T. L. L. Temple, III, Southern Pine Lumber Co.; William Van Beckum, The Pacific Lumber Co.; and G. F. Prange, Secretary for the Committee and special staff member appointed by NLMA.

Preserving Markets Through Treating Wood Theme of Nov. Mid-West St. Louis Meeting

The Preservation of Forest Products as a Means of Preserving Wood Markets will be the main theme of the Midwest Section meeting, November 3–4, in St. Louis, Mo., according to Ira Hatfield, program chairman. Headquarters will be the Holiday Inn.

Meeting Program

Three technical sessions and an Official Luncheon are planned for the annual fall event. During Session I, papers will deal with upgrading wood as a means of meeting competition, and a comparison of different methods for evaluating water-repellent preservatives for treated millwork. The underlying thought will be that treated wood can compete with substitute materials.

"The Rewards of Research for the Forest Products Industry" will be the theme for the second session. Papers will discuss: preservative problems that need research attention, the role of colleges and universities in promoting interest in wood preservation, and how wood preservation can extend the use of various species.

The theme for the last session will be "How Water-Repellent Treatments have Extended the Wood Treating Field". Papers will deal with preservative treatment of ponderosa pine millwork by the vacuum process, wood preservation should extend beyond poles, piles, ties, and so forth, and the place of water-repellent preservative treatment as seen from the military procurement standpoint.

The first and second sessions will have "Name your Problem" discussions after presentation of the papers.

Light Motion Study Shows Packaged Lumber Saves Time

BY PLACING LIGHT BULBS on the wrists of two workers, the many motions it took them to unload 5 boards is shown. This light motion study was undertaken recently by Mr. Leonard Koenen, Mayfair Lumber Co., and Mr. Howard Carlson, Signode Steel Strapping Co., both of Chicago, Ill.

TO COMPLETE THE STUDY a light bulb was attached to the end o a boom. Illustrated are the few movements that were necessary unload a package of lumber containing over 160 boards.

Wood and Water Theme of Nov. Carolinas–Chesapeake North Carolina Meeting

"Wood and Water" will be the theme of the Carolinas–Chesapeake Section annual meeting in Charlotte, N. C., Nov. 6 and 7, W. R. Smith, program chairman reports.

Particular emphasis will be placed on the drying of lumber, veneer, and particles or chips, and on the maintenance of satisfactory moisture content in the processing and use of wood and wood products.

High-temperature drying will be discussed by Dr. W. W. Calvert, Ottawa Forest Products Laboratory. John Lutz, U. S. Forest Products Lab., Madison, Wis., will speak on high-temperature drying of veneer, and Robert L. Youngs, also from the Laboratory, will talk on the stresses induced in lumber by the drying process.

FPRS Nat'l Executive Board to Meet Nov. 7 in Chicago

The Annual Fall Meeting of the FPRS National Executive Board will be held Nov. 7, at the Sheraton–Blackstone Hotel, in Chicago, Ill., F. J. Rovsek, executive secretary, announced.

One of the main areas of consideration will be how FPRS can more effectively serve management of the forest products industries. Other areas of discussion will be the Society's membership growth, a review of income and how this might be increased, and cooperation of the Society with the newly formed American Institute of Wood Engineering.

Fall Meeting Planned by Rocky Mountain Section

The Rocky Mountain Section plans to hold a fall meeting on Nov. 13, Lincoln A. Mueller, Section secretary reported recently.

Included in the program will be discussions on timber resources, harvesting methods, sawmilling, and financing. Program chairmen for the meeting are L. A. Mueller and Harry Troxell.

In recent action, the executive committee of the Section appointed a new chairman and vice chairman to serve out the balance of the year. They are: Robert S. Bader and James Whitney, respectively.

Beech Utilization Topic of Northeast Meeting

Better Utilization of Northeastern Beech will be discussed at Montpelier, Vt., Nov. 6 and 7, at a joint meeting of the Utilization Division, Northeastern Loggers Assoc., and the Vermont Bureau of Industrial Research. Headquarters will be the Pavilion Hotel.

Topics to be presented include: Availability of Beech, Logging and Handling, Air and Kiln Drying, Structural Use, Pallets and Containers, Railroad Ties, Flooring, Beech for Fuel and Charcoal, for Veneer and Plywood, for Pulpwood, and for Turning and Furniture. "Cultivating Markets for Beech Lumber" will be discussed by Paul Kneeland, Worcester, Mass., who will give the banquet address.

The program was arranged by Fred C. Simmons, USFS. Arrangements for attendance should be made by notifying the Vermont Bureau of Industrial Research at Northfield.

Southern Project Tests Wood Exposed to Summer Conditions

The temperature of wood in fram houses exposed to summer condition is now being studied through a joi project of the Texas Forest Servic and the Southern Pine Lumber Co forest service officials reported recentl

The purpose of the project, now underway at Diboll, Texas, is to dete mine the range of maximum tempera tures that can be expected to affect th structural members of a house. Bot the immediate and cumulative effect of temperature are to be evaluated.

Temperatures are obtained through a series of thermocouples installed in the house during the construction period. The tests will continue for the duration of the warm fall months. The Southern Pine Assoc. and the Forest Products Laboratory, Madison, Wis., are also co-operating in the study.

Outdoor Storage of Wrapped Lumber Safe, Western Pine Assoc. Reports

Dry lumber properly wrapped i paper or plastic film can be stored out doors at least a year, according to the Western Pine Association.

A 12-months study recently completed at Portland, Ore., by the association's research laboratory, found that such wrapped lumber changed less tha 2.5 per cent in average moisture co tent despite being sloshed by 3 inches of rain. Wrapping costs vari from $1.14 to $2.06 per thousan board feet.

Wrappings tested were a reinforc paper lumber wrap and a polyethyle film. Both are products carried at lum ber retail yards for use in constructi work. Details of the findings can obtained in Research Note No. 6.7 from the Western Pine Assoc., Yeo Bldg., Portland, Ore.

NEW PRODUCTS—LITERATURE

New Single Panel for Sheathing and Siding

Dubl-Bilt, a product that combines sheathing and siding in a single panel, has been added to the line of laminated wood fiber wallboards made by The Upson Co., Lockport, N. Y. Dubl-Bilt consists of two ⅜-inch panels welded together to a total thickness of about ¾ inch and is available in panels 4 feet wide by 8, 9, and 10 feet long.

Designed for board and batten construction, the firm reports that it has been accepted by the FHA for use on studs spaced either 16 inches o.c. or 24 inches o.c. It comes primed two sides, primed one side, and plain two sides. The thermal conductivity is 0.43 BTU.

Descriptive literature and a sample of Bubl-Bilt may be obtained without charge from The Upson Co., PR Department, Lockport, N. Y.

Heavy Duty Router Bit

A new heavy-duty industrial-style router bit has been designed by Deluxe Service Tool Corp. A thick carbide cross section is used to provide extra strength.

The Luxite Router Bit reportedly allows more re-sharpenings. It has diamond wheel finish grinding of all carbide surfaces and is made of alloy steel. Heat treated, the bit is furnished in a plastic cylinder for safe storage. Single, double, and 3 flute styles are available. More information can be obtained from Deluxe Service Tool Corp., 1108 Grand Ave., North Bergen, New Jersey.

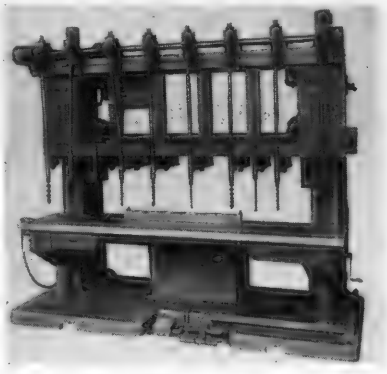
New Dorr–Oliver Booklet

"Board Plants by Dorr–Oliver" is the title of a new two-color booklet about the design and engineering services offered by Dorr–Oliver Inc. to board producers and wood products industries. Also included in the pamphlet are flowsheets of typical board plants designed by the firm and a tabulation of potential markets for various types of boards. Copies of the bulletin, No. 8002, are available from Dorr–Oliver Inc., Stamford, Conn.

Vertical Double Borer

A vertical, double-column, multiple borer, "Style CFH", is now being produced by the B. M. Root Co., York, Pa. The design includes an open back for work to pass on to other production-line operations.

The boring cycle is operated by a hydraulic feed system. Automatic continuous and intermittent feeds are provided. Treadles are used for setups and emergencies.



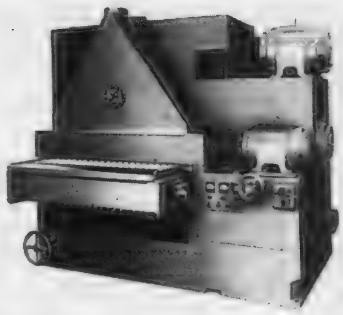
The "CHF" borer will accommodate up to 26 universally adjustable spindles. The totally enclosed spindle gears are of heat-treated alloy steel and bronze, with generated spiral cut teeth. The boring length capacity is 8 feet by 6 inches in front of the machine's columns, and 6 feet by 6 inches between columns.

Equipment regularly furnished with the machine includes an air blower for chip removal, two spring-pressure adjustable hold-downs, a back fence with reversible end stops, and two tool drawers for the work table. More information is available from the B. M. Root Co., York, Pa.

Combination Drum and Belt Sander

The new Yates–American belt sander combines drum and belt sanding operations on one base and frame, according to the firm. The drum brings material to size, and belts do finish sanding. A superior finish can be obtained in one operation, the firm reports.

Belts can run either over a conventional serrated roll or over a flexible



platen. A slotted contact roll for the belt is available with different degree of angles and durameter of rubber to obtain a variation in aggressiveness of belt action and finish. The 103-inch belt comes in 43 or 55 inch widths with speeds variable from 3800 to 6000 surface feet per minute.

Belt tracking is automatic with air control, and belts can be arranged to operate with or against the feed travel. Massive construction of the unit keeps vibration to a minimum. The feed drive is enclosed in the base of the machine.

All controls are at operator's position and a jog button is provided for preliminary tracking of the belt. More information is available from the Yates–American Machine Co., Beloit, Wis.

New Berthelsen Brochure

"Engineering for Industry" is the theme of a 16-page brochure released recently by Berthelsen Engineering Works, Inc. The booklet covers the design and engineering scope of the firm's staff and facilities in addition to the construction features of Berthelsen hydraulic hot presses. Copies are available from Berthelsen Engineering Wks., Inc., Box 1423, Lockport Rd., Joliet, Ill.

NAMES IN THE NEWS

C. D. DOSKER

C. R. LOCKARD

C. D. Dosker, Sr., president of Gamble Bros. Inc., has recently been appointed to the Forest Research Advisory Committee by Sec. of Agriculture Benson for a 2-year period.

The appointment of **Charles R. Lockard** to a newly created post in the Washington office of the U. S. Forest Service was announced recently. He will take charge of a

project to establish national log grades. Until his transfer, Mr. Lockard was chief of the Division of Forest Utilization Research at the Northeastern Forest Experiment Station.

Appointed Vice President of Research and Development for TECO, research affiliate for NLMA, is **William H. Scheick.** Mr. Scheick, who succeeds Carl A. Rishell, was executive director of the Building Research Institute and Building Research Advisory Board before joining TECO.

Forestry Suppliers, Inc., of Jackson, Miss., has announced the opening of a West Coast office with **Eugene D. Marshall,** forest products consultant, as its West Coast representative. A consultant since 1953, Mr. Marshall previously headed the Forest Products Dept. of Texas A. & M. College.

Dr. Harold B. Gatslick has recently been appointed associate professor in the department of forestry and wildlife management at the U. of Mass. College of Agriculture. Dr. Gatslick will be responsible for developing the departmental program in wood technology and utilization.

Richard C. Rodenbach, a 1958 graduate of the School of Forestry at Duke University, recently joined the staff of the North Carolina Piedmont Hardwood Forest Research Project as a research forester. He will conduct research in both hardwood utilization and forest management.

Arthur W. Nelson, Jr., will head the new Timber Products Division of the Champion Paper and Fiber Co. as general manager the firm announced recently. Mr. Nelson will be in charge of the firm's 600,000 acres of timberlands, and the development and marketing of the products that can be obtained from these properties.

North Carolina State College's School of Forestry has recently been organized into departments. **Dr. T. E. Maki,** Carl Alwin Schenck Distinguished Professor of Forest Management, is the head of the new Dept. of Forest Management. **Dr. James S. Bethel,** acting head of the college's graduate school, is the head of the Dept. of Wood Products.

Recently appointed executive vice president of Fjellman American, Inc., is **Mr. Urs Brennwald.** He will be in charge of sales and will supervise technical problems.

NEW PUBLICATIONS

Mississippi Forests. This report was designed to provide up-to-date information on the kind, amount, and condition of forest resources, the industries they support, and the possibilities for improving wood production. Available from the Southern Forest Experiment Station, New Orleans, Louisiana.

Semi-Annual Statistical Summary of Lumber and Hardwood Flooring 1955–1958—Production, Shipments, Orders and Stocks. The statistics in this report are based on mill reports to regional associations and on estimates of production published by the Bureau of the Census, U. S. Dept. of Commerce. Available from the Nat'l Lumber Mfrs. Assoc., 1319 Eighteenth St., N. W., Washington 6, D. C.

Program of Work, 1958–1959, of the Forest Products Laboratories of Canada. This report lists project work undertaken by the Ottawa and Vancouver Laboratories for the period June 1958 to May 1959. Available from the Dept. of Northern Affairs and Nat'l Resources, Ottawa, Ontario, Canada.

Five Year Progress Report on Status of State-Wide Service Test on Fence Posts. M. R. Childs. Contains field service tests on approximately 5,900 fence posts that have been set in fence lines at fourteen locations throughout the state of Texas. Research Note No. 22. Available from the Texas Forest Service, Lufkin, Texas.

The Marginal Sawlog for Southern Yellow Pine. Milton Applefield. This study appraises the economic significance of residue pine pulp chip production and makes an analysis of the use of small, low-grade sawlogs entirely for pulp chips. Research Note No. 21. Available from the Texas Forest Service, Lufkin, Texas.

The Forests and Forest Industries of Australia and New Zealand. J. H. Jenkins, Reprint from Timber of Canada. Available from the Forest Products Laboratories of Canada, Ottawa, Ontario.

Sixth Biennial Report of the Forest Products Commission of the State of Washington. This report covers the time span of July 1, 1956, to June 30, 1958. Available from the Institute of Forest Products, 303 Anderson Hall, U. of Washington, Seattle 5, Wash.

EMPLOYMENT SERVICE

The FPRS Employment Service is operated without charge as a service to members. Companies or institutions with positions to be filled or individuals seeking employment may participate in this program by inserting a free ad in two consecutive issues of the FOREST PRODUCTS JOURNAL. Inquiries concerning employment listings or ads to be placed in the JOURNAL should be addressed to FPRS Employment Service, P. O. Box 2010, University Station, Madison 5, Wis. Correspondence is kept confidential.

Positions Offered

E–318—A technical specialist needed fo Northwest association. Must be under 4(with practical experience in technical serv ice and research. Duties will entail organiz ing and maintaining a high-quality technica service primarily through personal contac in the field, directed toward governmen agencies, builders, architects, and lumbe distributors. Will assist the associatio manager and aid the research committee i executing their annual program. (Oct.)

E–321—Wood utilization engineer needed for large furniture manufacturin plant. Experience in furniture and allie fields preferred. Salary commensurate wit experience and ability. (Nov.)

E–322—Assistant veneer sales manage needed. A person with an educational back ground in forest utilization or wood tech nology preferred but will waive these re quirements for a man with equivalent back ground in veneer sales. Position require two to four years active veneer sales, mak ing up veneer lines, and pricing veneers Advancement to position of Sales Manage possible within six to seven years. (Nov.)

E–323—Quality control supervisor needed Age range desired is 21 to 28 years old. Educational background in wood utilization with an interest in research and quality control preferred rather than sales. Prior business experience will be waived for a recent graduate who has the potential to establish and maintain a systematized quality control program. (Nov.)

Employment Wanted

No. 487—Position desired where there is opportunity for advancement. Has 1 years experience in kiln drying and general forestry. Married. (Oct.)

No. 488—Industrial engineering position desired with large woodworking firm, preferably multi-plant organization, furniture, veneer, or plywood. Will consider short-term assignments on a consulting basis. Graduate of German university with a degree equal to a B.S. in furniture manufacturing and industrial engineering. Completed apprenticeship as cabinetmaker and passed journeyman and master examinations with honors. (Oct.)

No. 491—Position desired in produ t development, sales, and sales engineering in particle board industry. Holds B.S. i wood utilization. Experienced in productio of furniture, cabinetmaking and partic board manufacture. (Oct.)

No. 492—Person with an M. S. in Forest Management desires position. Has e perience in logging, photogrammetric work, and forest management research. Married, available Jan. 1, 1959. (Nov.)

FPRS FOREST PRODUCTS JOURNAL
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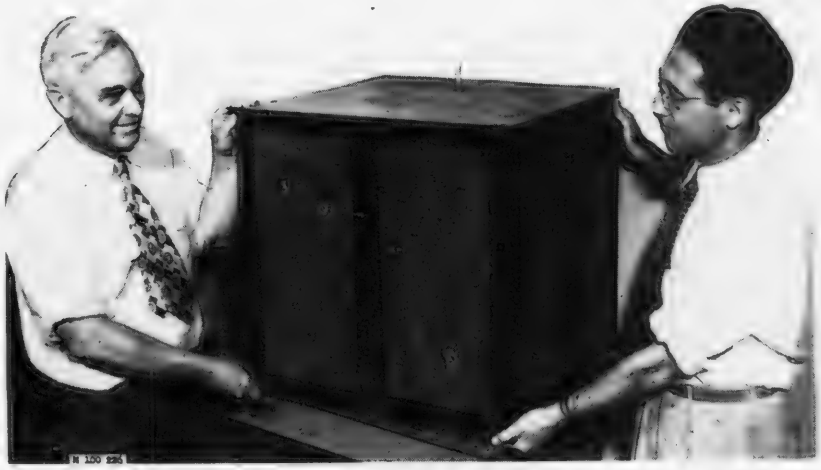
MORE WOOD RESEARCH...

Essential for National Security

HON. GEORGE H. RODERICK
Assistant Secretary of the Army

"We need brilliant men for research—trained—educated —dedicated to advancement. The Armed Forces are no exception, and neither is the wood industry!"



Shelters of wood fiber diffusion board, developed at US FPL, could protect our troops from atomic fallout, poison gases.

I AM INDEED HONORED to have been asked to speak here today, and am grateful for the many courtesies which have been extended to me so warmly. My past affiliation with the wood industry and my contacts with the Forest Products Research Society make this occasion somewhat of a homecoming. In my current position I do not work with wood directly, but in no position, even in the Armed Forces, can one disassociate himself from wood. The Army, for example, is organized along the three lines of men, money, and material, and wood is used by men, bought with money and is one of our major materials.

During my tenure of office as Assistant Secretary of the Army it has been my duty, and my pleasure, to attend many meetings and forums, but I am completely amazed by the programming for this annual meeting. The wide range of technical sessions and committee meetings are indicative of the objective, broad interests of the membership of this Society. Since its inception about a dozen years ago, the Forest Products Research Society has grown from a few dedicated individuals to almost 3800 members and subscribers, positive proof of the interest in and importance of one of this nation's most important raw materials. My first introduction to your membership and activity was your meeting in Grand Rapids in 1949. I attended nearly all of the meetings and was impressed by your first—I believe—machinery exhibit held in conjunction with the annual sessions. This Society has filled a critical need for an organization which brings together the many skills required for the improved utilization of wood.

I note with special satisfaction the keynote session "Insurance for the Future . . . through Forest Products Research" and the session on the educational programs in forest products. In this age of struggle between Communism and Freedom, we cannot afford to stand still. We must progress in all matters, and this requires research. Obviously, we need brilliant men for research—they must be trained men—educated men—and men dedicated to advancement. The Armed Forces are no exception, and neither is the wood industry.

With respect to wood, the Commission on Increased Industrial Use of Agricultural Products in its report to the 84th Congress expressed its views this way: "Wood is a complex material, physically, mechanically, and chemically. Although it has been under intense study with the means available for many years, it must be confessed that we are yet ignorant in many ways as to what it is, how it is put together, and what makes it behave as it does . . . In order to use this remarkably diverse and versatile material to the best advantage, we should know all we can about it . . . Knowledge in this field . . . is still inadequate for the tasks ahead . . ."

Upon analysis, and if this statement is true, there are revealed two major weaknesses: first, the research forces directed to this purpose have been inadequate; and second, essential basic scientific knowledge is inadequate.

Official Luncheon Address, FPRS 12th National Meeting, June 22–27, 1958, Madison, Wis.

The Author: Hon. George H. Roderick holds a BS degree in mechanical engineering from the University of Michigan. He joined the American Seating Co. in 1923 and held several important positions as vice president including manager of the war products division, research and development; manufacturing; operations. He became a director in 1947, and also served as director of the Newport Steel Corp. Mr. Roderick was appointed to his present post in 1954, where his work has been primarily financial management.

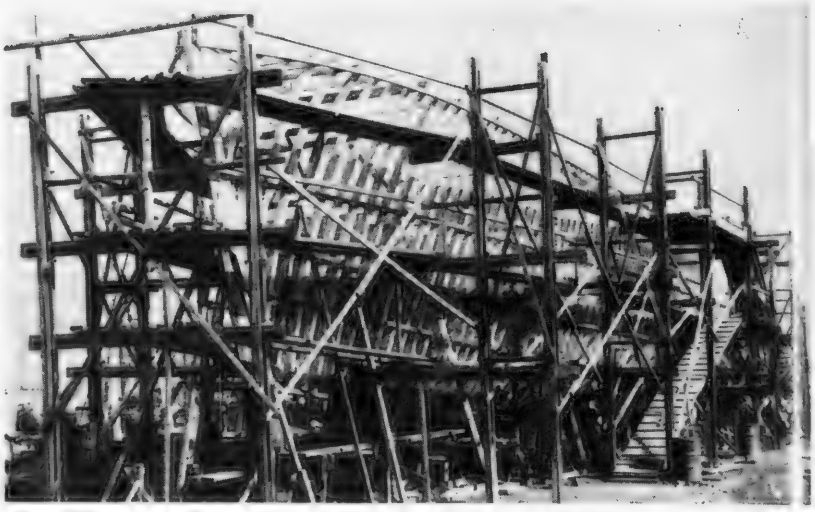
These weaknesses exist in spite of the magnificent and objective work of the U. S. Forest Products Laboratory, The Forest Products Research Society, a number of our universities, and the wood-using industries. The need for continuing research is exemplified by the outstanding program for this 12th Annual Meeting of your Society.

Certainly, I do not mean to belittle the fine scientific and engineering developments that have accomplished revolutionary changes in the wood products field. But particularly I wish to emphasize that in forest products, as in all other wonders of nature, there are vast areas still listed as "unknown" not only to laymen but to scientists and researchers alike.

Why should the Armed Forces be interested in these matters? Well, first of all, the Armed Forces use large quantities of all kinds of products from wood in its simplest forms—poles or lumber to complex specialized products like diffusion board. In World War II, the Armed Forces used 70 billion board feet of lumber! During the peak year of that war, one-half the nation's lumber production—17 out of 34 billion board feet—went into packaging and crating. Currently we need containers for everything from beans to missiles. In fiscal year 1957 the total purchase of lumber by the Armed Forces was about 421 million board feet at a cost of approximately $40 million. As for paper—I suppose someone might know, but I could not begin to find out how much of what kinds of paper is used annually in the Pentagon's programs for the Army, Navy and Air Force. I can assure you it is in the same area of thinking as space exploration.

In addition to these large quantities of conventional forest products, the Armed Forces need many *special* products made from wood. A number of these have had to be developed to serve a particular purpose. For this type of research the Department of Defense calls upon numerous facilities such as the Forest Products Laboratory, our universities, and our industrial laboratories. A few examples will serve to illustrate the wide range of these skills and the facilities required for development of these special products.

Critical in an emergency would be glycerine—an essential ingredient of of some explosives—*now* derived chiefly from petroleum. The Forest Products Laboratory was asked to develop a method for making this chemical from wood waste so that widely dispersed plants could be built close to a readily available source of raw material. The Laboratory met our needs by developing two processes considered quite satisfactory should such a situation arise. This is just one of many Laboratory-developed products that have application for industrial uses as well as military. This example is typical of many research efforts where the product or process developed by a *single* research project benefits *both* civilian and military activities.



USS Bittern, the unique all-wood ship made with a hull of laminated, pressure-treated red oak. She was specifically designed to be a non-magnetic minesweeper.

Further, the Defense Department is interested in many other products made of wood fibers. A very specialized product recently developed by the Forest Products Laboratory under a contract with the Army Chemical Corps is called fiber diffusion board. It is a relatively cheap wood fiberboard that filters out poison gases, disease-laden particles, and radioactive fallout from nuclear fission. It would possibly be used for shelters for the protection of troops or civilians from most of the deadly effects of radioactive fallout from nuclear weapons. This fiberboard has the appearance of home-construction building board, but is impregnated with chemicals that screen out the deadly gases and other harmful particles. Life-sustaining oxygen, on the other hand, passes through it freely.

Truly, this is a remarkable result of intense research because it might permit a population to continue its habitation of an area poisoned by surprise attack. Though not the ultimate in protection, it *has* placed us one step closer to preserving our way of life.

We may turn to our sister service—the Navy—for another example. The wide variety of wood and wood products required to keep the fleet afloat are provided through systematic research and development in cooperation with industry and research institutions. In this day of atomic submarines, speedy luxury liners, and Forrestal-class carriers, it is significant that the inherent function of wood remains as an indispensable renewal structural material continuously available for progress in new development and design.

On 4 March 1957, as testimony to this use of wood in our modern Navy, at the Consolidated shipbuilding yards in New York the USS Bittern was launched. The unique and revolutionary element here was a new-type wooden hull of pressure-treated red oak and made of laminated construction throughout. Its mission . . . a non-metallic mine hunter. Many years of research in basic fields preceded the construction of this prototype ship. Amidst all our modern developments, wood remains a truly remarkable engineering material in the struggle of men and materials against the sea.

It might also be interesting to note here that the oldest boat in active Navy service has a *wooden* hull. It is a 50-foot barge, registry number C–182. Launched in 1912, she is still afloat and assigned to the Potomac River Naval Command in Washington, D. C.

These examples of accomplishment in research and development serve only to illustrate the Armed Forces' needs for and their serious interest in wood and wood products. These same examples illustrate also that, in meeting the Communist threats successfully, we must continue and even expand further our search for knowledge.

Sometimes these efforts lead us into a search for knowledge far afield from the immediate practical problem. This is characteristic of basic or fundamental research, which is well known to

During the peak year of World War II, half the nation's lumber production (17 billion board feet) was used in packaging and crating.

this audience. I am sure each of you knows of examples where basic studies resulted in "break-throughs" which led to important commercial products. One of these was a priest's explorations into the nature of acetylene, which led to the development of synthetic rubber. Another was a long study of heavy molecules for the purpose of extending scientific knowledge which resulted in the discovery of nylon. I need not expand on the impact of this discovery on our everyday lives. More recently, a group of University of Michigan chemists delved into the fundamental properties of boron-hydrogen compounds. What they found led to the development of high-energy boron rocket fuels now used particularly by the Air Force as a rocket propellant. Who knows? Perhaps this fuel will place a man on the moon!

We do know, however, that our application of existing knowledge in the development of new things or new products is limited only by the depth of our current knowledge. The opportunities are as many as the stars, but they must be pursued vigorously. Basic research, from which stem new developments, is truly an obligation of industry, educational institutions, and government. Without basic research, our commercial and industrial complex would soon be at a standstill and would stagnate. Within the Department of Defense, our satellite and missile programs could not have been developed without the background of basic study of the physical nature of matter which, when known, could be applied to the development of the atomic bomb and to modern weaponry. Now we have Explorers and Vanguards—not as Buck Rogers's dreams but as actualities—and the ultimate is still beyond imagination.

The Army and its sister Services have never lost sight of the tremendous importance of industry's contribution to the Industry-Defense Team. More than ever before in history the military strength of our nation can be nothing without the complete backing of its industrial strength. Field Marshall Montgomery once said that success in battle is one fifth tactics and strategy and four fifths supply. I would certainly agree with that formula, and hastily add that it is also true to a great degree in our present struggle to preserve peace.

We are dependent in many ways upon industrial, educational, and governmental institutions for the answer to many of our problems. True, many of our military roadblocks have been eliminated by our own technical services, but many of our basic answers have come from other sources. Such a source is the U. S. Forest Products laboratory, an organization of widely diversified talent, equipment, and personnel second to none in the world in its field. Much of the Laboratory's research in the past years has directly and indirectly aided in the establishment of integrated operations and fuller utilization practices in wood and wood products. In this situation, our country has available a cooperative research program of a laboratory that is utilized not only by us in the military but also by many of you here in industry. Last year, the Forest Products Laboratory operated on about a three-million-dollar budget, of which approximately one third was sponsored by the Armed Forces.

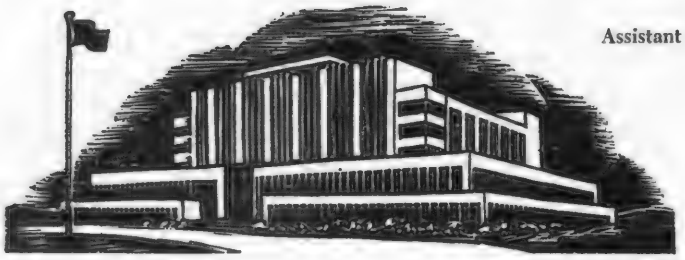
The shortage of highly trained personnel in the fields of wood technology reveals a real need to stimulate interest in the field of education, especially on the undergraduate level. We *must* train more people in the forest products field—not only wood technicians, but physicists, chemists, and other scientists. We must assist more students to become intensely interested in sciences, and to advance their education to high, practicable levels in their chosen fields. The universities are one of the training grounds for these scientists who, when well prepared, can accomplish the needed basic research upon which application is so dependent. I am confident that the deliberations at this 12th meeting of your Society will help to solve the problems of obtaining the people needed for research in forest products. It is a problem of common interest to industry, education, and government.

At this point I would like to inject some thinking of the Army in this field of research and all other important areas of our interest.

In doing its job, the Army has never lost sight of the overriding importance of certain intangible matters of the spirit. No research in wood utilization, missiles, or other weapons is worth a dime if the men who use the resulting products are lacking in courage, discipline, or obedience to the national good. No grouping of soldiers into new types of organizations can help us in any way unless they are devoted to a common cause and are led by forceful, dedicated men. We are convinced that we must give as much attention to the qualities of *leadership, force* and *courage* in our fighting men as we give to research and new facilities.

So to you here today and to the companies and institutions you represent, the Armed Services salute your past achievements and eagerly anticipate your continued help in the solution of our common problems. Certainly, the problems are difficult in these trying times, but I am sure that we all have full confidence in the American concept of freedom of thought and in the ability of our individuals and institutions to meet any challenge. You of the Forest Products Research Society deserve full credit for bringing into focus on these problems the widely diverse skills and interests found in government, industry, and education.

THE ROLE OF Federal Government IN FOREST PRODUCTS RESEARCH[1]



V. L. HARPER
Assistant Chief, Forest Service, U. S. Department of Agriculture

Federal objectives in forest products research are three: to reduce waste in primary harvesting and utilization, to find uses for parts of the forest crop not now economically useful, and to improve general serviceability of forest products.

QUITE A FEW YEARS AGO, a man who had much to do with the founding of the Forest Products Laboratory at Madison put our essential problem in these words:

"In our use of forest products we have been drawing on the balance of resources which has accumulated during the remote past. We now see very plainly that in no long time this balance will be exhausted. . . . It is a wholly new thing that a great people like ours should be face to face with the situation that it must depend for its supply of wood upon the annual growth. It is a new thing that a people should be placed in a position where the annual growth of timber will be the substantial limit of the amount which that people can use."

Those words were spoken by Charles R. Van Hise, the president of the University of Wisconsin who entered into the agreement with the Forest Service that created the Forest Products Laboratory as a research institution unique in the world.

We are today, 38 years later, at the point where President Van Hise predicted we would be "in no long time." As forests grow, that is about a generation of trees. In most of our forest regions, we are substantially dependent upon annual growth; only the West still yields appreciable amounts of timber accumulated from the remote past, and proportionately less each year with relation to its own second-growth harvest.

From its very beginnings, forest products research by the Forest Service has been closely linked with some of our great educational institutions and with industry. This fact has a prophetic significance. No one agency can do the job alone. There is simply too much to do; too many problems to solve nationally, regionally, locally; too many different sets of conditions that seldom remain constant for long and, changing, they require fresh thinking, new approaches. In a very direct manner, therefore, we in forest products research are concerned with product utility and consumer requirements—a fact that leads inevitably to the question: How have our products fared?

Trends in Forest Products Consumption

The most recent evidence on this point has just been published by the Forest Service in Forest Resource Report No. 14, "Timber Resources for America's Future." It shows that, while there have been marked shifts in kinds of timber products used, total consumption of industrial wood has increased over-all since 1900—to some extent.

During recent years we have consumed as a nation more industrial wood than at any time before—we consumed more than 10 billion cubic feet a year. Per capita consumption of industrial wood has dropped substantially in recent decades, but in 1952 it still totaled 66 cubic feet for every man, woman and child. This still relatively high per capita use, the report emphasizes, is significant.

Lumber still comprises well over half of all industrial wood consumed, and despite a drop of more than one-half in per capita consumption of lumber, total consumption in 1955—because of increased population—was at early 1900 levels. Total lumber demands are expected to increase in the future, even though lumber will continue to decline in relation to other timber products.

Pulpwood and veneer bolts will continue to take more and more of the total timber output. Per capita consumption of pulpwood has tripled since 1920, and total consumption has risen more than five times.

On the other hand, wood products such as poles and piling, mine timbers, and cooperage is expected to increase only moderately.

The report projects potential timber demands to 1975 and 2000. While three projections are made, this presentation will be confined to the so-called "medium" projection. This projection is based upon an assumed population of 215 million in 1975 and 275 million in 2000, a gross national product of 630 billion dollars in 1975 and 1,200 billion in 2000; and upon a price structure relatively unchanged from 1953.

The medium projection puts potential demand for sawlogs 34 per cent higher in 1975 and 91 per cent higher in 2000 than 1952 consumption. Pulpwood demand is projected to rise 103 per cent by 1975 and 182 per cent by 2000. Total demand for industrial wood may go up 50 per cent by 1975 and 114 per cent by 2000.

So there you get an idea of what we will need in those milepost years of 1975 and 2000, and of what we must produce from what Van Hise called the "annual growth" of timber. It is an eye-opening challenge to all engaged in forest production and utilization research.

The cold fact of the matter is that, unless much more efficient utilization is effected than assumed in the Report, annual growth will have to be more than doubled by the year 2000 to supply the projected demands. This means

[1] Presented at Session III, Keynote Session, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

The Author: V. L. Harper holds BS and MS degrees in forestry from the University of California. He later earned a PhD from Duke University in economics and forestry. Harper has been with the Forest Service since 1927, and has held several research posts.

Research leaders from private industry and educational institutions meet with government researchers to plan and direct coordinated studies on ways to improve wood utilization.

a rise in growth from the 1952 level of 47.4 billion board-feet to 105.4 billion—an increase of 122 per cent. It will be a colossal task to substantially increase the efficiency of forest utilization, confronted as forestry is today with an unchecked trend toward declining size and quality of standing timber and changes in species composition of our forests that leave us with less and less of the desired softwoods and more and more of the relatively unwanted hardwoods.

Products Must be Up-Graded from the Raw Material

Under such conditions, one of the important roles of forest products research is plain: To develop techniques and processes that can transform low-quality raw material into high-quality goods capable of much longer service life. Fortunately, we have had some experience along this line already!

Federal research in forest products began some half a century ago on a scale small indeed by today's standards. Virtually from its beginnings, however, it was aimed at improved service and prolonged service life of wood products. The early strength tests were undertaken to provide engineers with reliable data on which to base more efficient designs for wood structures, thereby using less wood. Research on preservatives and treatments had as its objective the thwarting of decay fungi. The early seasoning research was pointed not only toward faster ways of getting the water out of green wood but toward reduction of seasoning losses as a result of checking, splitting, honeycombing, and the like, and toward developing techniques for drying the refractory hardwoods and thereby making them useful. For example, sweetgum became a popular furniture wood only when the seasoning problem was solved.

Within a few years after it was founded, the Forest Products Laboratory was looking into the possibilities of pulping hardwoods, in effect moving directly counter to the popular notion that, except for limited use as filler for book stock, hardwood fibers were simply too small. And by the mid-twenties, work was under way on the semichemical pulping of hardwoods, a process that is today in wide and expanding use, producing well over a million tons of paper a year from aspen, oak, maple, birch, elm—virtually the whole miscellany of hardwoods that dominates our eastern forests. Pulp yields, incidentally, are up considerably from those obtained with the older chemical processes.

Illustrative of how research benefits can multiply, however, is the development of an even more efficient process during the past decade. In its cold soda process, the Laboratory has made available to industry a less costly means of pulping hardwoods, with pulp yields even greater! Needless to say, industry is adopting these research results; one mill is already enlarging its first cold soda plant.

This powerful trend toward utilization of hitherto unused species is paralleled by one of equal significance: the conversion of sawmill, veneer-mill, and other residues into fiber products. The product possibilities have broadened so greatly that we are rapidly attaining reality for a long-standing dream of our research people—truly integrated utilization of woods-run logs.

Naturally, with these developments, products research at the central laboratory is becoming more closely intertwined with other forestry utilization research. Research in this field has been undertaken at regional Forest Experiment Stations, with the Laboratory cooperating and furnishing technical guidance, and thus we are in a better position to work closely with other agencies, public and private, on various kinds of utilization problems.

Almost from its inception, the Forest Products Laboratory has done cooperative research for other branches of the federal government. During World Wars I and II, that cooperation monopolized its facilities and staff. A considerable amount of research continues in cooperation with the Air Force, Navy, and Army on problems ranging from the packaging of military supplies to development of improved materials and structural components for aircraft and ships. We have even entered the space age by attacking problems involving missiles, space vehicles, and the transport of goods beyond the earth's gravitational field!

Research Objectives

At this point let us summarize forest products research objectives. There are three. The first is to reduce waste in harvesting and primary utilization by finding ways of improving operations and using leftover material for industrial goods. The second is to find industrial uses for those parts of the forest crop not now economically useful, among which are cull and defective trees left by the harvest, whether because of natural deficiencies or external causes, species not now economically useful, and thinnings and improvement cuttings below the level of economic return. The third objective is to expand and improve the general serviceability of forest products through improvement and expansion of existing products and processes, creation of new goods and processes, and integration of products from wood with new products and other industries.

To meet these objectives, the research program is directed generally toward solution of the most pressing problems of the producers, processors, and users of forest products. Basic research, however, is emphasized to the fullest extent possible. Only through basic research can essential wellsprings of information be tapped to find solutions to our manifold problems of applied research and development. For example, our efforts to make use of the lignin residues of chemical pulping have had little success because we don't really know what lignin is.

Forest Service Responsibilities

As Forest Service research objectives make clear, the responsibilities of federal research in forest products are broad. The scope of these responsibilities is re-emphasized almost daily at the Forest Products Laboratory by the broad fields of activity represented by its visitors, its correspondence, the innumerable requests it receives for information and guidance. To fulfill its function properly, federal research

must be staffed with topflight scientists, engineers, and technologists in the various fields of forest products utilization; its scientists and engineers must carry on the broadest program of studies possible, and must keep in the closest possible contact with producers, processors, and users of forest products in all parts of the country and with research institutions in their own and related fields.

But, however extensive this program, we recognize that it cannot begin to handle, nor should it try to handle, all of the Nation's utilization research. For this reason, a basic tenet of our policy is to encourage universities, state agencies, and private concerns to carry on research programs, and to cooperate with them to the fullest extent.

While the responsibilty of federal research is broad, all publicly supported research has much the same obligations. State-supported universities and certain other public institutions are similarly charged with acquiring and disseminating information on problems confronting forestry in its broadest aspects. Our interests are therefore mutual; and, to be fully effective, all of this widely dispersed research effort ought to be coordinated. The Forest Service should be in a favorable position to work with nonfederal public and school agencies on the coordination of research programs to bring about a well-balanced nationwide attack on all problems important to forest products utilization.

All publicly supported utilization research, moreover, has a responsibility to cooperate with private industry. The forest products industries have developed a strong interest in research, and certain segments—notably pulp and paper—devote in the aggregate much greater funds to it than are available to public institutions. The most recent comparative figures available are for 1953. These show that federal forest products research funds were $2,750,000, other public funds aggregated $1,700,000, and industry spent $26,550,000. In 1957, federal funds had risen to $3,000,000 and other public funds to an estimated $2,700,000. Industrial expenditures undoubtedly also went up.

Naturally, the bulk of industrial research effort goes into product development; our competitive markets compel this. But industry relies heavily upon publicly supported research for fresh ideas, processes, and techniques, as some of the examples cited will substantiate. Because of the character of so much of our industry—the small size of its units and its highly competitive nature—public research has a deep obligation to serve its needs—with this proviso: that the public good shall govern when conflicts of interest arise.

Collectively, all agencies have a large responsibility in their utilization research that takes into account the forest resource from which come our wood raw materials. How well are we discharging that responsibility?

To answer that question, we must face up boldly to the basic problems that confront us. They shape up like this: we are confronted not alone with the situation that we must soon get along henceforth entirely with what Van Hise called the "annual growth" of our forests; we are also faced with the concommitant fact that our forest quality is declining and our forest composition changing, and it is a gravely complicating fact.

Somehow, we must replace softwood lumber in some uses with relatively plentiful hardwoods, which are harder to cut and nail, harder to season, harder to keep from splitting and warping.

Somehow we must find uses for the low-quality stands, the little-used species, the thinnings of young forests, both to meet our wood requirements and to help timber producers finance the stupendous task of restoring the quality of our forests.

Somehow we must do a more efficient job of utilizing what we harvest—the limbs and tops and damaged trees now left behind in logging, the sawdust and shavings and other residues at the mills.

And finally, we must somehow find means of making wood products of all kinds more serviceable, more resistant to decay and fire and insects, and more durable in use.

What Should be Done?

In view of all this, it seems that we are doing too little, and that we cannot much longer proceed at our present pace if we are to discharge our responsibilities. The problems we face are huge, but not insuperable.

Industry and other private research in forest products utilization undoubtedly ought to be stepped up, and this is likely to occur. Certainly there is much reason to believe this would be desirable. Public supported utilization research—that is, federal and non-federal public research—similarly might well be stepped up. And this could best be achieved by a program coordinated to the best of our abilities.

We believe that a greater federal effort is justified and would in itself stimulate other agencies to increased effort. Cooperation there must also be, and in that context we think that the federal program—when expansion is feasible—should appropriately provide for contract or other aid with nonfederal agencies. This not only could help to accomplish research more efficiently but could help forestry schools and other units of universities to provide the all important training of future scientists and research workers that we all will need. There is precedent for this in existing agricultural and forestry programs that affords useful guides to procedure.

It seems almost superfluous to mention that a great deal of thought has been given to research expansion—the worthwhileness of expansion, how much expansion, for what, and so on. The dividends of past forest products research have been great. How much, in dollars and cents, our investment has returned is of course impossible to compute. A few years ago, however, the Forest Service conservatively estimated that, from six of its Laboratory developments alone, industrial ventures have sprung that annually pay federal taxes amounting to $70 for every federal dollar spent on the research that made their existence possible. Certainly the other benefits in terms of jobs, business opportunities, and new or better products far exceed the mere tax return. But great as the dividends from past research have been, the future dividends are likely to be much more impressive. Moreover, there are cogent reasons for getting ahead faster on forest utilization problems—one notable example being the problems inherent in the low-quality timber of much of our forests and the dependence upon solution of those problems for an improved forest management of our vast acreage of small woodlands.

Over-all, what scale of program for forest products research is justified? Frank Kauffert and William H. Cummings, reporting on this question for the Society of American Foresters in their published report of 1955, "Forestry and Related Research in North America," concluded that forest products research ought to be expanded in the near future four times the $31,000,000 expended by all agencies in 1953. This may be a conservative estimate, but regardless of how high ultimate goals may be set, a substantial expansion ought to be started soon, and at a rate as fast as each agency—private, state, and federal—finds it feasible to go.

Such increases all along the line will give us a reasonable chance to do the work that needs doing—now—if we are to pass along to our heirs and successors forests and forest products on a scale at least equal to that we ourselves enjoy. We have already postponed over-long the payment of premiums adequate to insure for them the resources they will need.

THE ROLE OF Private Industry

IN FOREST PRODUCTS RESEARCH[1]

WINTON PATNODE
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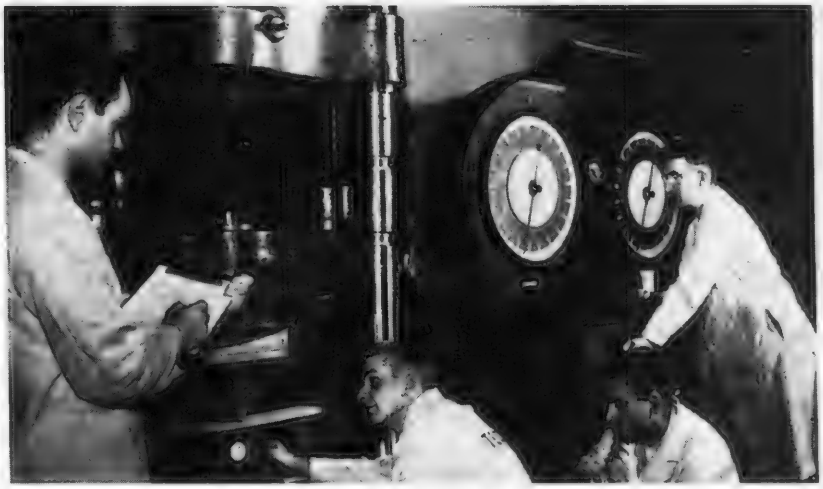
Integration is a good thing for the forest products industry. In the future, more large units will perform a greater proportion of the broadly applicable, fundamental research necessary for the development of new products and processes.



In 1953, industry invested 85% of the dollars spent for forest products and utilization research.

THE THEME OF THIS 12TH NATIONAL meeting of the Forest Products Research Society is "Insurance for the Future—through Forest Products Research", a forward-looking sentiment implying self-reliance and the determination to achieve. Voluntary gatherings of this kind, to discuss work of common interest, are a part of the culture of American industry, and they are fruitful. The exchange of ideas stemming from freedom of thought and speech, followed by individual decisions to act or not to act, is vital to American industry, it is also vital to productive industrial research.

The word "vital" is used deliberately. Aware as we are of the diabolically intricate and expensive hardware of some research projects, let us not forget that only a man can have ideas. Ideas do not crawl out of the machinery.

[1] Presented at Session III, Keynote Session, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

The Author: Dr. Patnode earned his PhD in chemistry at Cornell University. He was employed by General Electric for 24 years, where he specialized in administration of research operations. He joined Weyerhaeuser Timber Co. in 1955 and was Director of Research and Development until the spring of this year.

Invention, one of the goals of industrial research, is a mental act, the product of an individual mind, disciplined by knowledge but unfettered. Profitable commercial exploitation, the other goal of industrial research, hinges upon the decision to buy or not to buy, also a mental act, the conclusion of an individual mind. The development of discoveries and inventions by persons working in harmony with each other and with their times, results in products that are commercially successful when people appreciate the value of what is offered and decide to buy. These two ingredients, applied science and technology coupled with attractive values in the market place, spiced with competition and sweetened with profits, are the essence of productive industrial research.

The products of the forest, from telephone poles to cellophane, are so numerous and varied that one has to think about them one at a time, or to group them in classes. One classification that has been found useful divides the products generally into two groups: those which are instantly recognized as products of the forest, such as Christmas trees and lumber, and those which the user does not ordiarily recognize as forest products, such as rayon and vanillin. Industrial research applied to each of these two groups has different objectives and different frames of reference, although there are also some aspects in common.

Research on Recognizable Forest Products

First, consider products that the user associates with the forest. Research on this group of forest products has been going on for about a million years, ever since man first timidly descended from the trees at dawn and retired to their safety at dusk. Man's first home was the forest—and his last home is often a simple pine box. Call it race memory, vestigial animal instinct, or just good common sense, the fact is that people generally associate the products of the forest with home, with security, with pleasure, with eternity. People want wood-burning fireplaces, fresh flowers and greenery in their houses, picket fences and a stick to whittle. Who does not instinctively stroke the surface of fine wood in a furniture store, or sniff with pleasure the fragrance of pine gum and of freshly cut wood? In winter, man turns to his woodworking shop, and in summer to the forest for creative fun and relaxation. In a word, people like wood. Even the cave man, whose house was of stone, used a wooden club in the tender act of wooing a mate!

There is much talk today in marketing circles about motivational research,

subliminal advertising, the "hidden persuaders". The desire for our natural products is part of our race inheritance, and it needs no artificial psychological stimulation. Researchers in forest products should never ignore this fact.

But man is a creative animal, a restless and ambitious creature. He seeks change and is sometimes fascinated by novelty. Not content with conquering the surface of the earth, the seven seas, and the atmosphere, he is now determined to go to the moon. Not that we should send a representative along to plant Lunar Tree Farm Number 1, although equally fantastic proposals may be read in the papers every day, but neither should we abandon the traditional natural forest products in favor of dramatic novelties.

We have here the makings of a dilemma posed by the inherent desire of the customer for the natural and familiar products of the forest, and his equally strong attraction to artificial and synthetic products of creative novelty. The dilemma can never be resolved by mere complacency with the old, nor by frantic embrace of substitutes. The familiar properties and utilities of forest products need to be retained, but continuously and subtly modified so that they will meet new needs in new ways in tune with new times.

For this class of products, the ones the user recognizes as coming from trees, the most profitable areas of development probably lie in processing, packaging, and distribution. Many members of FPRS are working in these areas; their active participation in the work of this Society, and what they will do at home as a result of this participation, will benefit the industry.

An industry, however, which thinks in terms of a cycle of decades in tree farming for perpetual yield of its raw material should take an equally long view with relation to the future of its products. Look, for a moment, at the fields of science that are developing rapidly and that may have important applications to wood. It would be profitable to know more about the effect of high-intensity radiant energy, such as sound, pulsed square waves of electricity, micro-wave power and bombardment by sub-atomic particles on the surfaces of the fine structure of wood. It would be profitable to examine the current trend of polymer chemistry involving the formation of polymers of desired configuration rather than heterogeneous mixtures, and the orientation of selected polymerizable monomers on surfaces of chosen configuration prior to polymerization. Also, study the recent discoveries and current trends in biochemistry involving enzymatic reactions and the effect of molecular geometry on disease and immunology. We are inclined to forget that a log is still a botanical product once it gets into a manufacturing plant, and that advances in knowledge of the physics and chemistry of other cellular substances may be applied to ours. Work in these fields is undoubtedly applicable to processes involving adhesion, seasoning, stabilization, preservation, and finishing.

Products Not Associated with the Forest

Now let us consider the vastly more varied products of the second classification, those which are, and can be, made from forest raw materials and which the customer does not immediately associate with the forest. Here the sky is the limit, subject only to the ceiling imposed by economics, now and in the future. Products composed of bits and pieces, fibers, extractives, and derivatives of forest plants find their way to market in an almost infinite variety of forms. It is difficult to think of these diverse operations as one industry, and we are forced rather to think of them as the pulp and paper industry, the naval stores industry, the fiber panel industry, parts of the chemical industry, and so on. They form a single industry only in the degree to which their operations are integrated back to the forest, and the degree to which they use the whole tree. The unifying principles are thus the raw materials and integrated organization and ownership rather than similarity of products. And the economic necessity of integration in manufacture forces the organizational integration of widely varied fields of research.

Integration is a good thing for the industry, since it engenders a broader outlook on the part of management, a greater awareness of the extent of competition, and appreciation of the opportunities for diversification of products as a means of approaching more complete utilization of the raw materials. The forest products industry of the future will inevitably include more large units than exist today, more groups of closely associated firms who trade actively over the back fence as do some of the modern complexes of the chemical industry, and the future will bring greater adherence to the principle of sustained yield for perpetual operation. Concurrently we shall see the formation and expansion of more competent research groups, and the performance by the industry of a higher proportion of broadly applicable scientific research, leading to products now unknown and permitting hitherto unattainable improvements.

Those of you who share these sentiments, and who are actively engaged in research and development work should get out the books, read the journals, and by all means take an active part in the scientific or engineering society of your profession. Prepare yourselves to think about and to work productively in a broader field of activity than that in which you are presently engaged. Lean less heavily upon your suppliers of materials and equipment, and know more about their application to your business than they do. Be aware of trends and discoveries in as many fields of science and technology as you can, and be alert to apply them to your business. You are going to have to do this to insure your future, and to help your industry avoid the fate of some who have complacently ignored the unceasing change around them.

This Society has an active and able group in the field of chemical utilization. At the risk of seeming repetitious and perhaps presumptuous, they should be reminded not to overlook the so-called minor forest products. For example, the technical press recently announced another step in the world-wide study of native remedies and medicines to be conducted by a west coast college, sponsored by a large manufacturer of pharmaceuticals. Their objective is the discovery of the active principles of primitive medicines, many of them forest products. A forest industry might well undertake the isolation of such products. This is but one small part of the intense interest in biologically active materials produced by wild plants. We should be aware also of the declassification of military research on methods of isolating and purifying ingredients of complex mixtures of chemicals, knowledge of which may permit the recovery of valuable components of waste process fluids.

Summary: Research is Vital

In summary, we must agree that research in forest products is vital to the future of the forest industry. Many units of the industry will find it profitable to widen and deepen the scope of their research efforts, guided by the predictable needs and desires of their chosen market. While persons engaged in this effort may not literally land on the moon, figuratively and intellectually they have the opportunity to shoot the moon. Working with wood, we have the excitement of exploring new frontiers, of developing profitable new products and processes. We have also a heart-warming reward in knowing our work helps to satisfy a universal human need for the comfort, the health, the cheer, and the safety of home.

THE ROLE OF Educational Institutions IN FOREST PRODUCTS RESEARCH[1]

H. L. SHIRLEY and E. C. JAHN
Dean, and Associate Dean and Director of Research, State University College of Forestry at Syracuse University

Our industry spends more than $31,000,000 a year on research, but only $550,000 of it in our schools. This ratio is inadequate if we expect to turn out the quality of research men needed to insure the future of the forest products industries.

THE SUBJECT ASSIGNED for today's panel is a good one. If it leads to some soul searching on the part of all of us it will be worth while. If we only acquaint one another with our mutual problems it will still be worth while. If we can come to a real understanding of the magnitude of the task we face and can set about drafting a pattern to meet it, it will be one of the most significant things that has happened to American forestry and forest products industries since the first sawmill started operating.

The Questionnaire

The task assigned for this paper is to discuss forest products research in the colleges and universities. Letters on this subject were exchanged between Dean Frank Kaufert and Dean H. L. Shirley. Dean Kaufert, as Project Director for the Society of American Foresters' study on "Forestry and Related Research in North America", collected excellent material for this survey in 1952 and 1953. Dean Kaufert recommended that fresh data be obtained to bring his study up to date, rather than to review his report. Therefore, that curse of college presidents, deans and even professors, was resorted to—the mimeographed questionnaire. This was sent to all schools and departments of forestry, as well as many agricultural and engineering colleges, experiment stations, and technical institutes.

	Questionnaires sent	Replies	No. reporting products res.	Per cent return
Accredited Forestry Schools	27	27	26	100%
Non-accredited Forestry Schools	14	10	6	71%
Agric. and Eng. Colleges, Expt. Stations and Tech. Institutes	62	28	3	45%
Total	103	65	35	

The data, therefore, represent nearly a complete report on the forestry schools and departments. It may be assumed that the four non-accredited schools that did not reply have little or no forest products research. Practically no forest products research was reported by engineering and agricultural colleges (except for those having forestry departments that are therefore included with the forestry schools). Yet, among engineering colleges, there are significant pulp and paper programs at the University of Maine and the Institute of Paper Chemistry, the furniture program at North Carolina State College, and the housing, farm building, and construction programs at Minnesota, Illinois, and Massachusetts Institute of Technology, and certain others. The emphasis in engineering colleges, however, is not on wood as a material, but rather on a specific end-product or on an industry that happens to be using wood among its other materials.

Likewise, the agricultural colleges, though reporting very little direct forest products research, do have an interest in the use of wood, such as in the construction of farm buildings, structural tests, and the use of wood-lot material for fence posts, and so forth.

These peripheral areas of forest products research in engineering and agricultural colleges are not included in this paper, since these institutions did not report upon them as forest products research. Furthermore, state, federal, or private research laboratories, though located at universities but independently operated and not a part of the college-administered program, are not included.

The questionnaire, prepared by Dean Shirley, asked for factual information on the current budget and the budget 10 years ago, the sources of funds, the capital in the form of buildings and equipment available, the number of men engaged on a part-time and full-time basis, the number of graduate students involved, and a listing of active forest products research projects. Also, opinions were asked concerning major objectives of

The Authors: Dean Shirley originally planned to deliver this paper at the Keynote Session, but went to Europe to receive an honorary doctoral degree from the University of Helsinki, Finland.

E. C. Jahn holds BS and MS degrees from the New York State College of Forestry and a PhD from McGill University. He was with the U. of Wis. before he joined NY State at Syracuse as Professor of Forest Chemistry.

[1] Presented at Session III, Keynote Session, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

forest products research, the main problems needing attention, the best distribution of research effort, and the value of products research to undergraduate and graduate instruction. We wish to express deep appreciation to the many department chairmen, deans, and professors who gave their time to fill out the questionnaire for this study.

Tabulation of Results

The major findings have been summarized and are presented in tabular and other form. Tables 1 and 2 present the research expenditures for forest products for the present and 10 years ago, and show the sources of funds. In the past decade, expenditures for forest products research have increased six-fold and are now in the order of one and a quarter million dollars annually. During the same period, total forestry research at the colleges nearly quintupled, reaching about three million dollars (see also Table 3).

During 1957–58, about half of the products research was supported by college budgets, with the remainder shared almost equally by federal agencies and industry grants, with only small sums from other sources. This represents a sharp rise in sponsored or outside-supported reesarch over a 10-year period; from about $50,000 to about $650,000, or 13-fold.

Table 3 and Fig. 1 show that the figures for research expenditures for 1947–48 and 1957–58 take their places about as would be expected from the 1953 data of Kaufert and Cummings. These figures also show that the percentage of products research expenditure in relation to the total forestry research expenditure has increased somewhat since 1953. The desired distribution of research, as expressed by the several schools, averages 60 per cent for land management and 40 per cent for forest products. Fourteen of the schools reporting stated that this ratio should be 50:50.

Table 4 shows that the forest products research effort varies widely, as is well known, between the schools. The annual expenditure for about half of the schools is less than $20,000 each.

The equipment and facilities available are set forth in Table 5.

It is in the interest of the forest products industries that these college and university laboratories be utilized fully for research in the forest products field. Furthermore, various engineering colleges and agricultural engineering departments have equipment that can be made available from time to time for research on wood products, even though this equipment is devoted generally to other use.

The number of men engaged in full-time and part-time research in the forestry schools and the number of graduate students specializing in this field are set forth in Table 6. Considering that these are nation-wide figures, the total is not impressive and is far below what the number should be if the schools were meeting fully the responsibility imposed on them in terms of the great importance of the forest products industries to the national economy and the pressing need both for research and an improved competitive position for these industries.

The classification of active forest products research at the several schools is arranged below in the order of increasing number of projects by class.

Research area	Current projects	Major problems needing research
Wood improvement	1	
Log grade and recovery	3	1
Logging and sawmilling	4	2
Pulp and paper	4	3
Utilization, general	4	10
Wood machining	5	2
Economics of products	5	3
Use of low grades and residue	5	9
Materials packaging	6	6
Quality control	7	5
Veneer and plywood	8	1
Properties of wood	9	13
Glues and gluing	10	2
Marketing	10	1
Wood preservation	11	5
Mechanical properties	11	3
Laminated wood and joints	11	0
Chemical utilization	12	3
Growth—quality relations	14	5
Composition board	18	4
Wood seasoning	21	1
Miscellaneous	24	5

Table 1.—RESEARCH EXPENDITURES BY ACCREDITED FORESTRY COLLEGES (26)

Source of funds	All types forest research		Products research	
	1957–1958	1947–1948	1957–1958	1947–1948
College	$1,728,000	$488,100	$ 615,400	$162,900
State and local agencies (other than via college)	136,200	27,900	12,300	5,400
Federal agencies	418,000	51,400	280,000	25,100
Industry—open grants	297,300	7,100	226,400	6,600
Industry—confidential	54,000	2,400	48,800	840
Other	205,000	10,000	57,100	1,900
Total	$2,838,500	$586,900	$1,240,000	$202,740

Table 2.—RESEARCH EXPENDITURES BY ALL COLLEGES (34[1])

Source of funds	All types forest research		Products research	
	1957–1958	1947–1948	1957–1958	1947–1948
College	$1,799,700	$506,400	$ 640,000	$169,700
State and local agencies (other than via college)	205,400	41,900	23,600	5,900
Federal agencies	536,000	76,400	301,300	33,600
Industry—open grants	297,300	7,100	226,400	6,600
Industry—confidential	54,000	2,400	48,800	840
Other	217,000	12,700	66,100	3,400
Total	$3,109,400	$646,900	$1,306,200	$220,040

[1]26 Accredited Forestry Colleges.
6 Non-accredited Forestry Schools and Departments.
2 Agricultural College Experiment Stations.

Table 3.—GROWTH OF RESEARCH IN ACCREDITED FORESTRY COLLEGES

	All types of forest research	Products research	Per cent of expenditure[1] in products research
1947–48	$ 586,900	$ 202,740	35
1953[2]	1,680,000	550,000	33
1957–58	2,838,500	1,240,000	44

[1]Desired Distribution of Research
Land Management — Ave. 60%
Forest Products — Ave. 40%
[2]From "Forestry and Related Research in North America" by Frank H. Kaufert and William H. Cummings, Society of American Foresters, Washington, D. C. (1955).

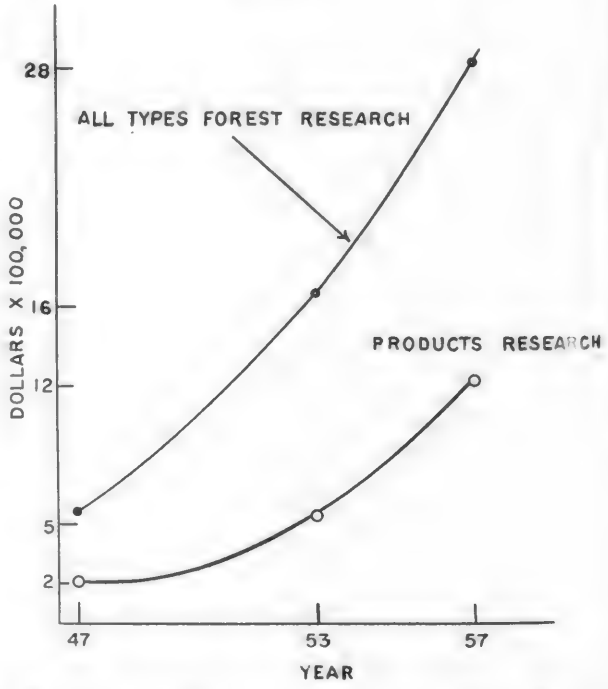


Fig. 1.—Expenditures for research in accredited forestry colleg

Table 4.—DISTRIBUTION OF RESEARCH EXPENDITURES FOR FOREST PRODUCTS RESEARCH IN 1957–58

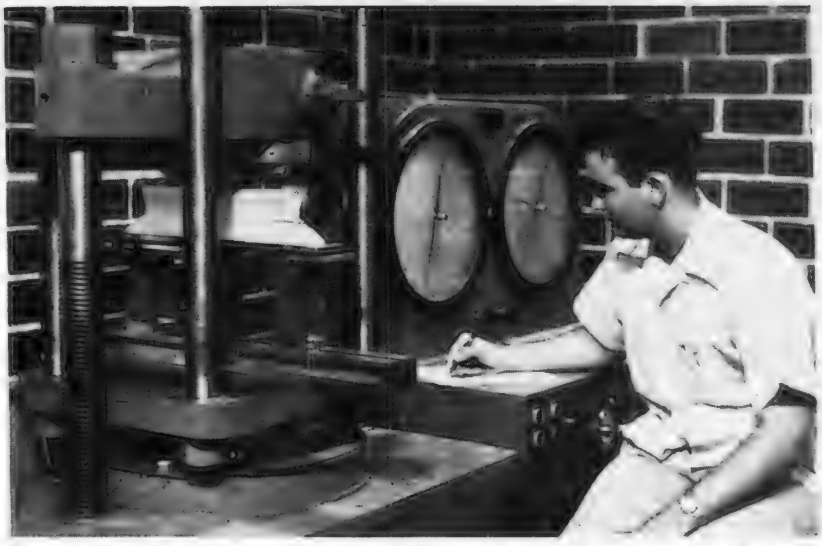
Amount of expenditure	Number of colleges reporting: Accredited colleges	Total schools
None	3	6
$ 000–10,000	5	8
$1 000–2C,000	4	5
$2 000–40,000	7	7
$4 000–80,000	5	6
$8 000+	2	2

What Should the Schools be Doing?

If we think of the task of the schools as primarily that of preparing men for research, then one is obliged to ask: are the projects on which the schools are now working those best calculated to support the educational program, or are they oriented more towards what the schools feel to be the interests of the wood products industries? Are there too many projects dealing with products, such as particle board, hard board, plywood, lumber and wood preservation, and too few dealing with subjects such as machining of wood; bonding of wood, particularly the interaction of glue with wood; the action of finishes; the movement of moisture and other substances through wood in liquid and vapor form; the physical and chemical nature of wood; and the study of the factors responsible for variability in physical properties such as hardness, elasticity, density, strength, and the behavior on seasoning? Is there too much emphasis on wood preservation and too little on the agencies causing deterioration of wood in service, especially insects and fungi? More especially, are the schools engaged in research in forest products taking full advantage of the resources of their university, particularly in the departments of biology, physics, and chemistry, to make sure that diversified talent is brought to bear on research in wood? These are the types of questions that need to be constantly raised at each school to make sure that its own research program in forest products is directed in a way that will enable the school to make the best possible contribution.

It is interesting that nearly all schools that filled out the questionnaire considered forest products to be important for undergraduate instruction and indispensable for graduate instruction (Table 7). It was also significant that among the foresty schools none of those now carrying forest products research plans to decrease its program, and many plan to increase the program or start one if they have none now available.

The survey just completed, though admittedly not covering all academic agencies engaged in forest products research, nevertheless brings out clearly where the bulk of the work is being done. It is not in the engineering colleges or the agricultural experiment stations but, rather, primarily in the colleges of forestry. The agricultural experiment stations that do have programs of significance are mostly those associated with colleges having a forestry department or school.



What will this man's training cost? About $36,000 by the time he receives his Ph.D.!

The aim of the Forest Products Research Society is primarily to promote the health and prosperity of the nation's wood-using industries. Some of these, of which the pulp and paper, veneer, and plywood industries are splendid examples, are prosperous and have shown the capacity to grow with the expanding industrial development of our country. Others such as the wood chemical industry, cooperage, wood box, fuel wood, lumber, post, poles, ties and mine timbers have shown a declining use or at least use has failed to increase as rapidly as has gross national production. In the case of lumber, there has been a decided increase in cost and prices with little increase in output. The lumber manufacturer is squeezed between high labor costs on the one hand and more remote and poorer quality stumpage on the other. The recent study by Zaremba on lumber prices reported in the March issue of the JOURNAL OF FORESTRY merits serious consideration by all of us.

Have we been trying to meet the problems of the wood products industries by concentrating on individual operations or end products rather than the industry as a whole? It would be somewhat like trying to develop the steel industry by concentrating all research on angle iron or I-beams rather than looking at the industry as a whole.

If we grant that the future of the forest products industries will to a large degree depend on research, and that this must deal with research on all phases of the industry, then it follows that the future of the industry depends on the research and educational programs in the forestry schools. No other units of the colleges and universities are concerning themselves with the problem from land to finished product, and no other research agency in industry or government must deal as deeply and broadly on forest products research as the men studying in the forestry schools. We can expect forest products research to benefit by the work done in engineering colleges, in chemistry, physics and biology, but the orientation and steering of the major programs needs the general knowledge and approach provided in the forestry schools.

If this key role of the forestry schools is recognized, then what should this mean for the schools? Obviously, more money, more and better students, more faculty, and better liaison with industry and the U. S. Forest Service. But it means something more —the schools must raise their own sights on forest products research, not just a little bit, but by a large amount. The schools must get over playing a minor role in forest products research; they must play a major role.

Cost of Graduate Education

It would be unwise to expect that every forestry school could educate men for all fields of research in forestry; in fact, a graduate program should be attempted only by those schools that have the resources of a strong university to draw on for talent in basic fields of knowledge related to forestry. It seems inevitable, how-

ever, that more schools will need to develop research programs in forest products if we are to turn out the number of qualified research men that industry, government, and the forestry schools will require.

The cost of research and of graduate instruction is high. How much does it cost to produce a top-grade research man, that is, a man with a Ph.D. degree capable of pursuing vigorously a research program with a minimum of direction, capable of supervising assistants, and knowledgeable enough to seek the help of men in related science when this is needed? A major professor capable of turning out strong Ph.D.'s is a man that will cost the university at least $10,000 a year. Such a man teaching graduate courses and conducting research could direct the work of an average of about six graduate students, of which we could expect about 3 to be graduated every two years. Stipends to furnish fellowships for 6 students would run about $15,000 annually. Add these together with supplies, equipment, and university overhead and the cost comes to about $54,000 a year or about $36,000 for each Ph.D. man educated. In 1953, Kaufert and Commings reported a total annual expenditure of $31,000,000 on forest products research, of which $550,000 were spent in the schools—$1 in the schools for each $55 spent by government and industry. This is not a proper ratio and must inevitably lead to waste of research money due to lack of properly prepared men.

In a program costing $31,000,000 annually, a total of some 1,500 research men would be required, assuming that each accounts for some $21,000 annually in expenditures. The longevity of a research man is about 30 years. Therefore, by simple calculation, a ratio of about 1 dollar should be spent in forestry schools for research in forest products for each $16.20 that is spent by government and industry. Any lower ratio is almost certain to mean that the Ph.D.'s are inadequately prepared, undergraduate teaching is neglected, or that the school is turning them out and not replacing their capital in terms of personnel and equipment.

Whose responsibility is it to see that an adequate proportion of total forest research takes place in the schools? Obviously it is mainly the responsibility of the schools themselves but also of government and industry that employs the graduates. The schools have the job of education; government must protect the interests of society as a whole; and industry is concerned with perpetuating itself and being prosperous. Properly trained manpower is necessary for all three cases. It is obvious then that a much greater research effort must be made by the schools, firstly to reach the level necessary to maintain the nation's present forest products research program, and secondly to permit this program to grow.

The above may be challenged as representing merely the viewpoint of the schools. There is another viewpoint—can industry and government expect to get their research dollars' worth from money made available to the schools? We know that the government spends huge sums in agricultural research through the land-grant colleges. Whether it gets its money's worth or not is, of course, difficult to analyze. We do know, however, that this is one of the means and perhaps the most significant means by which the productivity of the worker on the farm has been able to keep pace with that of his fellow worker in industry. But, both from a standpoint of government and industry, money spent in the schools can command a wider variety of talent than in commercial or industrial laboratories. Furthermore, the atmosphere for research is freer in educational institutions. There are, moreover, certain types of problems; in fact, the most important and significant ones of industry that can best be attacked by the pooling of resources to launch a substantial project at an educational institution rather than attempting to solve it by an individual company's research activities. Examples are the Empire State Paper Research Associates' program at the College of Forestry in Syracuse, where some 24 companies annually contribute money to sponsor research in the pulping of hardwoods. The Cellulose Research Institutes, newly organized at the College, is another such effort.

Table 6.—RESEARCH PERSONNEL IN FOREST PRODUCTS

	Accredited schools	Non-accredited schools	Total
Full-time staff	57	4	61
Part-time staff	93	8	101
Graduate students	151	0	151

Summary

The forestry schools have substantially increased their programs in forest products research compared to 10 years ago. However, the total research effort in the academic world is still far short of what it should be in order to provide the productive manpower to maintain and improve the total program of the nation in this field.

The need for this research is strikingly evident when we consider that the total research expenditure in forestry (all types) in 1953 accounted for only 1.1 per cent of the total national research expenditure. This is disproportionate to the importance of forests as a national resource and to the forest industries, which rank fifth or fourth in size and importance in the country. The present difficulties of maintaining the competitive position of wood in the national economy may not be unrelated to the low research expenditure in forest products compared to many other industrial products.

The forestry schools, because of the diversified talent on which they can draw, have a unique and important contribution to make to products research. Not only is it necessary that they conduct research to educate graduate students, but also that they give broad general direction to research as a whole and that all the talents that can be brought to bear on research in forest products are used. There is need particularly for broad comprehensive studies directed toward maintaining the position of wood in the national economy; something on which very little is being done at present. There is also great need for close collaboration and cooperation between the schools and the research agencies of industry and government. The schools can be particularly helpful in long-range problems of broad significance in which objectivity of a high order is required.

Table 5.—FOREST PRODUCTS RESEARCH FACILITIES

	1947–1948	1957–1958	Planned by 1965
A—Building space (square feet)			
Accredited forestry colleges (26)	156,171	385,912	583,900
Non-accredited schools (8)	9,551	30,700	40,500
Total	165,722	416,612	614,400
B—Equipment facilities (Dollars)			
Accredited forestry colleges (26)	884,087	3,337,014	6,479,000
Non-accredited schools (8)	32,000	85,000	150,000
Total	$916,087	$3,422,014	$6,629,000

Table 7.—VALUE OF FOREST PRODUCTS RESEARCH TO STUDENTS (As Reported by Accredited Forestry Colleges)

	Undergraduates		Graduates	
	No. schools reporting	Percentage of schools	No. schools reporting	Percentage of schools
No value	1	4	0	0
Desirable	12	48	1	4
Valuable	10	40	4	15
Essential	2	8	21	81

THERMOSETTING, EXTERIOR-PLYWOOD TYPE

Adhesives from Bark Extracts[1]

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Thermosetting resin adhesives for exterior plywood were developed by combining polyphenolic bark extracts with polymethylolphenol. This combination can be provided in a dry form or as a 40–45 per cent solids water solution that is quite stable at ordinary temperatures. The polymethylolphenol acts as a crosslinking and copolymerization agent. Formulations containing 49 per cent bark extract, 34 per cent polymethylolphenol, and 17 per cent filler are fast curing and produced acceptable exterior-grade Douglas-fir plywood.

VARIOUS TANNIN MATERIALS obtained from wood or bark sources have been used for centuries as complexing agents for protein as in the formation of leather. At least 30 years ago, some work was done in using tannins with protein in plywood adhesives (18, 19).[2] Starting in about 1940 and coming down to the present, there have been a number of proposals for utilizing tannins in phenolic resin applications such as in molding compounds (1, 17), laminating resins and plywood adhesives (3, 4).

Extensive studies on the use of tannin formaldehyde condensation products as plywood adhesives were made by Dalton (6, 7), Brandts (2), and others (23). McLean and Gardner proposed using tannin extracts from western hemlock bark either with formaldehyde or a phenol formaldehyde resin as a plywood adhesive (20). The commercial use of a fraction of Douglas-fir bark as an extender for plywood adhesives (15, 16, 27) may also have some association with the concept of tannin-polyphenolic resins. Combinations of Douglas-fir cork (24) with formaldehyde or with phenol and formaldehyde have been claimed as plywood adhesives. In other investigations, a tannin or a bark extract (26) was used as a component in a more or less conventional phenol formaldehyde polymerization reaction or as a reagent in the final plywood adhesive formulation (25).

An investigation of the possibilities of utilizing available coniferous tree bark tannins or bark extract products as raw materials in resins was initiated at Rayonier's Olympic Research Division in 1951. The primary goal was to prepare a thermosetting waterproof adhesive that would yield satisfactory exterior-type plywood. The specifications for this type of plywood as recommended by the Douglas Fir Plywood Association (5) were adopted for comparison and evaluation purposes. Although many investigators have endeavored to obtain boilproof plywood with tannin or bark extract adhesives, these attempts have been largely unsuccessful either from a plywood performance viewpoint or due to excessive cure time requirements or other economic reasons. In general, where success has been reported, the level of utilization of the tannin material has been quite low.

[1] Presented at Session VIII, Glues and Gluing, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis. Contribution No. 41 from the Olympic Research Division of Rayonier, Inc.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

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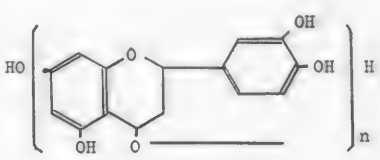
Extracts of Coniferous Tree Barks

Extraction Studies: Western hemlock *(Tsuga heterophylla)* is the species primarily used in our northwest mills for the manufacture of chemical cellulose. Since it was most available, it was chosen for investigation and proved to be the best source of components for adhesives. Extraction of this bark under various conditions of time, temperature, and chemical reagent concentration gave products that were obtained in gross yields up to 86 per cent of the bark. It was soon evident, however, that drastic reaction conditions gave products that were much less reactive and that optimum reaction conditions in terms of end use properties would have to be worked out.

It is not the purpose of this paper to describe the extraction process, but following extensive work an extraction process was developed that gave a product in the form of a dry sodium salt that is designated as HT-120.

Composition and Structure of Extracts of Hemlock Bark: The chemical structure of the more complex tannins has not been completely resolved, but available evidence points towards a polyphenolic polymer system. Spectrophotometric and degradative studies and functional group analyses that have been conducted at the Olympic Research Division of Rayonier (10–14, 21) have been helpful in providing a general structural concept of the predominant polymeric compounds that are present in extracts of coniferous tree barks. The normally water-soluble tannin portion of the bark is present in the extract together with closely related condensed tannins and a large proportion of the so-called bark phenolic acids. A possible monomeric unit for this complex mixture might be that of flavonoid suggested by the following structure:



This structural unit contains substituted resorcinol and catechol nuclei, both of which would probably be active in resin formation. Phenolic hydroxyl analysis by spectrophotometric methods (11, 21) gave values as high as 13.0 per cent.

Reactivity and Other Properties of Extracts of Hemlock Bark

Reaction with Formaldehyde: Evidence of considerable reactivity between hemlock bark extracts and formaldehyde was observed in preliminary studies. A "formaldehyde reactivity" test was devised to help in screening experimental products. The test consisted in allowing a dilute alkaline solution of the bark extract to stand at room temperature for four hours in the presence of excess formaldehyde. The amount or per cent of reacted formaldehyde was then determined by analysis. This test does not measure the total amount of formaldehyde that might under other conditions react with the bark product, but gives a relative value combining the factors of amount and rate of reaction, so that a great number of products can be screened by a conventional volumetric analysis procedure. Some extracts reacted with as much as 15 grams of formaldehyde per 100 grams of extract in this test, although values of 7 to 8 were more usual. As a rule, any extract with a cold formaldehyde reactivity value of below 5 did not give satisfactory performance in plywood adhesive tests.

End Use Tests: Performance data obtained by physical tests on end-use materials was also related to bark extraction variables. A standard plywood test that will be discussed later was developed for studying reactivity from the viewpoint of thermosetting reactions and other factors such as the resistance of adhesive bonds to delamination by moisture or weathering, attack by fungus or other degradative influences.

Viscosity Properties: In dealing with solutions containing appreciable concentrations of high molecular weight substances, some consideration must be given to viscosity limitations or variables. Very early in the study of bark extraction variables it was evident that some means of controlling product viscosity would have to be found. At the same level of use in an adhesive formulation, different extracts often had widely varying viscosity properties.

A study of the relative viscosity of the bark extracts themselves in a standard alkaline solution showed that viscosity or average molecular weight was dependent on the choice of extraction and processing conditions and to some extent was associated with certain variables in the bark. The viscosity of adhesive formulations closely paralleled extract relative viscosity curves, and thus the latter value could be used as a measure of product uniformity. Viscosity limits were set so that adhesive viscosity could be predicted and kept within a workable range as required by glue-spreading machines. In general, an alkaline solution of the bark extract containing 25 per cent total solids and with a pH of 10.5 was used for relative viscosity measurements.

Table 1.—GELATION TIME AT 50° C. FOR SOLUTIONS CONTAINING 20% T. S. HEMLOCK BARK EXTRACT AND FORMALDEHYDE

Formaldehyde concentration, % of extract solids	Minutes at 50. C. to solid gel
5	13
2	16
1	23
0.5	Viscosity increase only in 165 minutes

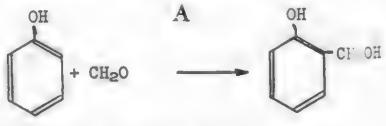
Development of Crosslinking Agents

Adhesive Formulations Containing Bark Extracts and Formaldehyde: Attempts to react extracts of hemlock bark with aqueous formaldehyde, paraformaldehyde, or hexamethylene tetramine gave variable results. Solutions of any appreciable concentration that contained formaldehyde or paraformaldehyde were very unstable when heated, and the bark extract was converted into an insoluble amorphous material. Even at room temperature, such solutions were not sufficiently stable for satisfactory use as adhesives. Gelation times at 50° C. for a 20 per cent T. S. solution of a bark extract are given in Table I. Hexamethylene tetramine added to the bark extract solution gave stable mixtures, this reagent being quite stable under alkaline conditions and at moderate temperatures.

Adhesive formulations containing 35 to 42 per cent total solids and composed of 12.5 parts of formaldehyde or equivalent and 20 parts of walnut-shell flour per 100 parts of extract had viscosities of over 1000 poises and were workable for only 15 minutes to a few hours at room temperature. Single 3-ply panels containing a glue spread of 100 pounds per Mdgl.[3] that were pressed for 10 minutes at 140° C. (285° F.) and 150 psi gave the results summarized in Table 2. Although bonding quality appeared to be good in some cases, water resistance was unsatisfactory and from a practical standpoint bark extract-formaldehyde formulations did not meet production or DFPA requirements.

Bark Extracts and Phenol Formaldehyde Condensates: Several solvents and reagents were tested with hemlock bark extracts in an attempt to plasticize the bark product and thus promote a more homogeneous reaction with formaldehyde so that bonding quality would be improved and plywood could be assembled in a reasonable period of time. Reaction of the extracts with phenolic novolac-type resins under alkaline conditions accomplished both of the desired ends. At this point, however, the presence of free formaldehyde in glue mixes was posed as being objectionable for reasons of toxicity and general nuisance. Conventional phenolic resin plywood adhesives or formulations were found to tolerate 10 to 20 per cent bark extract on a total solids basis (including fillers), but at higher usage levels (50 to 75 per cent) still required additional formaldehyde for satisfactory cure and strength. The final step in the development of the best cross-linking agent for bark extracts was the preparation of trimethylolphenol and polymethylolphenol condensates with high methylol content but no free formaldehyde. These reagents permitted the preparation of low viscosity, fairly high solids adhesive formulations containing as much as 75 per cent bark extract, and for best over-all results about 50 per cent bark extract on a solids basis. It might be argued that a considerable portion of such a formulation is actually a potential phenolic resin adhesive by itself, and that the bark extract is only an extender. On a per cent phenol basis, however, no commercial phenolic adhesive known to the authors can be extended to the degree allowed by the combination of polymethylolphenol and bark extract.

The Reaction of Phenol with Formaldehyde: Phenol reacts with formaldehyde as shown below. These reactions have been purposely oversimplified for illustration.



[3] Mdgl. denotes 1000 sq. ft. of double glue line.

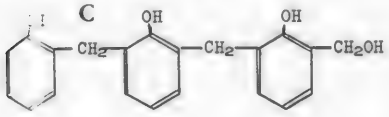
Table 2.—PLYWOOD[1] TEST RESULTS WITH HEMLOCK BARK EXTRACT-FORMALDEHYDE ADHESIVE

Formulation	Text series No.	Dry shear test[2] Strength, psi	Dry shear test[2] % Wood failure	Boiling water test[2] Wet shear strength, psi	Boiling water test[2] % Wood failure
Extract + Paraform	1	287	38	delaminated	
	2	351	87	122	35
	3	245	46	71	24
Extract + hexa	1	289	64	72	10
	2	349	94	170	35
	3	329	88	171	64

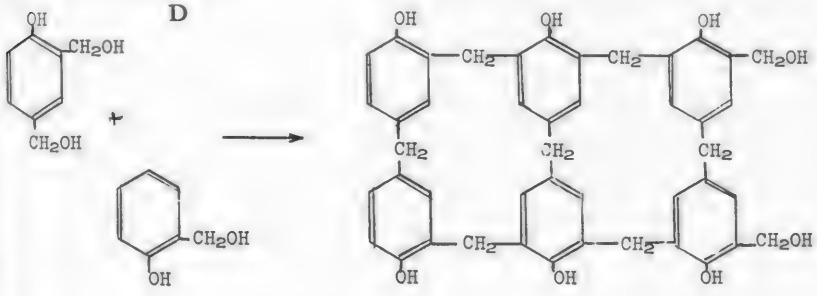
[1] ¼ inch, 3-ply pressed with platens at 140°C. (285°F.) and 150 psi for 10 minutes.
[2] Average results for 15 test specimens (3 panels).

The product, saligenin, is rather unstable and can react further with another molecule of phenol as follows:

If saligenin is heated alone, it forms a linear polymer of the novolac type:

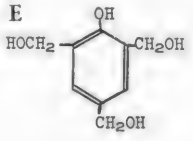


If more than an equimolar quantity of formaldehyde is present, some dimethylolphenol is formed. This compound can be condensed with itself or with monomethylol phenols to form a cross-linked structure:

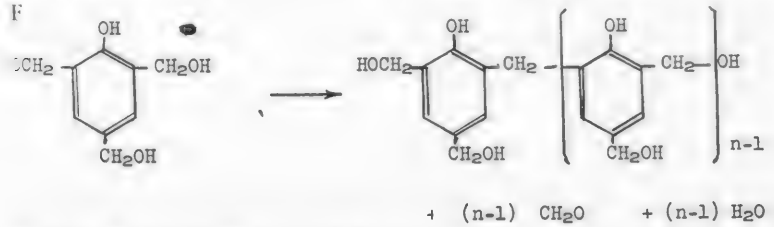


The resulting product will be infusible and insoluble, and is the type of resin desired for a boilproof adhesive.

By using excess formaldehyde with phenol under strongly alkaline conditions, it is possible to form trimethylolphenol:



Under alkaline conditions, trimethylolphenol is fairly stable, but when heated with phenol it can form the cross-linked strucure **D** or can form intermediate polymethylolphenols as in reaction **F**.



In place of simple phenol in the above reaction scheme, any phenolic compound can be used including our bark extract that contains many phenolic nuclei. In this case, trimethylolphenol or the polymethylolphenol reagent that we prefer, when put into solution with the bark extract, forms a combination that is stable for several weeks at room temperature and yet reacts rapidly when heated to form an infusible resin.

Preparation and Properties of Polymethylolphenol Reagents: The formation of trimethylolphenol **E** proceeds even at room temperature in a matter of days (22). Trimethylolphenol would have the maximum cross-linking potential. However, dimethylolphenol **D** or low molecular weight polymers with sufficient methylol groups **F** would also satisfy the requirement. Methylol groups and formaldehyde can also be destroyed by the Cannizzaro reaction **G**. The Cannizzaro reaction was studied extensively to find optimum conditions for forming desirable polymethylolphenol compounds.

At desirable concentration levels such as 40 to 50 per cent total solids content, the reaction of phenol with formaldehyde in the presence of sodium hydroxide (mole ratios 1:2.5–3:0.5–1) is very exothermic and must be controlled by cooling to prevent resinification and destruction of formaldehyde. By proper control, the reaction requires no external heat, and in a matter of 5 to 60 minutes at 90–95° C., depending on concentration, yields a product containing mostly low molecular weight ($n = 2$ to 5) polymethylolphenols with about 10 to 20 per cent monomeric di- and trimethylolphenols. Monomeric compounds predominate as reaction time at 90° C. is reduced to zero. Analysis for these compounds was made by known paper chromatography procedures (8, 9). Estimation of the degree of polymerization was based on analyses of product solutions to determine any free formaldehyde and formaldehyde destroyed by the Cannizzaro reaction. Such analyses coupled with viscosity and performance data allowed selection of optimum reaction conditions for the preparation of polymethylolphenol derivatives.

A 30-gallon resin kettle was used to prepare 250-pound batches of polymethylolphenol solution on a pilot plant scale. The kettle jacket was provided with water cooling and steam heat, and the kettle was fitted with an efficient reflux condenser. The kettle was charged with 61.2 pounds of U.S.P. synthetic phenol and 137.1 pounds of 37 per cent aqueous formaldehyde. These reagents were stirred and cooled to 20° C., and 51.7 pounds of 37.5 per cent aqueous sodium hydroxide was added. (Mole ratios, 1:2.6:0.75). After 3 minutes (50° C.), cold water was turned on to the jacket for 6.5 minutes (83° C.). The jacket was then drained and a temperature of 90° C. was observed 15 minutes after the addition of the sodium hydroxide solution. The reaction was then continued for an additional 40 minutes (90 to 95° C.), during which time reflux of volatile components occurred and prevented overheating. At the end of this time, cold water was turned on to the jacket to cool the contents to 50° C. The time required for the reaction cycle including cooling was 73 minutes. The polymethylolphenol solution contained no free formaldehyde, 43.5 per cent cured resin solids, and had a specific gravity of 1.195 and a viscosity of 44 centipoises at 25° C.

Reaction products prepared in this manner were found to contain 2.3 to 2.4 moles of formaldehyde combined with phenol, the balance (0.2 to 0.3) having been lost in the Cannizzaro reaction (Table 3). It is undesirable to use excess formaldehyde in the reaction, since formation of desirable dimers requires only the presence of 2.5

Table 3.—POLYMETHYLOLPHENOL PREPARATION

Mole ratio of reagents[1], Phenol: CH_2O: NaOH	Reaction temperature, °C.	Time: Minutes to maximum or subsequent combined CH_2O level	CH_2O: Moles Analysis of product		
			Combined CH_2O	Free	Destroyed by Cannizzaro Reaction
1:3:0.75	90–95	<10	2.51	0.37	0.12
		25	2.35	0.49	0.16
		40	2.34	0.32	0.34
1:2.52:0.125	90–95	30	2.14	0.36	0.02
1:2.52:0.25	90–95	15	2.24	0.24	0.04
1:2.50:0.50	90–95	10	2.34	0.13	0.03
1:2.50:0.75	90–95	15	2.36	0.06	0.08
		30	2.39	0.00	0.11
		45	2.35	0.00	0.15
1:2.55:0.75	80–85	21	2.5	0.03	0.02
		51	2.44	0.00	0.11
		96[2]	2.34	0.02	0.19
		141[2]	2.28	0.01	0.26
		171[2]	2.24	0.01	0.30
		201[2]	2.20	0.02	0.33

[1] In each series, the total weight of the reaction mixture was the same. Water was added at low NaOH concentration to compensate for weight difference. Concentration was based on the use of 37% aqueous formaldehyde and 35 to 50% NaOH.

[2] Corresponds to viscosity series of Table 5.

moles and any excess results in undesirable (in this case) free formaldehyde. Other phenols or mixtures may be used to form polymethylolphenols provided enough reactive positions (o, p) on the benzene nucleus are available. Natural phenol and mixtures with cresols were found to yield satisfactory polymethylolphenol compounds for reaction with polyphenolic bark extractives. In the sodium salt form, it was found that the polymethylolphenols could be spray dried and vacuum drum dried without appreciable damage. Dry-formulation adhesives could thus be prepared with a saving in transportation costs.

Although the preparation of polymethylolphenol reagents was carried out repeatedly on the above scale without difficulty, it is recognized that there would be some hazard in controlling the exothermic reaction on a very large scale that would require special design features. The problem is essentially one of increasing the ratio of surface to mass to allow rapid dissipation of heat. A continuous reactor as shown in Fig. 1 consisting of a long tube in a water bath providing an ambient temperature of about 90° C. or lower within the reactor was found to satisfy reaction requirements. This process would be adaptable to any size operation, and is particularly convenient and economical on a large scale.

Exterior Plywood Adhesive Formulations

Plywood Tests: A standard plywood test based on the preparation of ¼-inch Douglas-fir plywood in an 8 by 8 inch steam-heated press was used to evaluate experimental adhesive formulations. Plywood pressing time and temperature and other plywood process conditions were varied. All plywood was tested according to Douglas Fir Plywood Association (18) procedures. In most cases, dry-shear and cold-soak tests were eliminated, it being considered that a knife test combined with a boiling-water test would provide sufficient information to permit correlation of bonding quality and water resistance with experimental variables. Adhesive formulations that gave satisfactory bonding in preliminary tests were used to prepare larger panels in several standard veneer assemblies as would be used commercially. Cure time requirements for these constructions were determined, and in all cases the per cent of wood failure observed in broken test pieces was used as the criterion for determining adhesive quality.

Preparation of Adhesive Formulations: Thermosetting adhesive solutions were prepared by dissolving the bark extract in the sodium salt form in water and adding liquid polymethylolphenol reagent. The dissolving operation required shear-type mixing to break up water-coated powder. A common centrifugal pump connected to a circulation system was found to be very effective in dissolving the extract. Conventional glue-mixing apparatus with counter-rotating agitators also gave satisfactory solutions provided water and powder were blended gradually to form a viscous paste before final addition of remaining water, polymethylolphenol, and fillers.

Effect of Adhesive Formulation Variables on Viscosity and Bonding Properties: In the laboratory, the proportions of spray-dried bark extracts and polymethylolphenol solutions were varied in order to determine the most economical formulation, or that which contained the largest proportion of bark extract. With a standard extract, the effect of changes in the adhesive solids composition (excluding fillers) from 77 to 35 per cent in terms of bark extract content is illustrated in Table 4. The weight ratio of phenol to extract (0.15 to 1.0) was used in planning experiments, and clearly emphasizes the use of the extract as a replacement for phenol. A ratio of 1.0 of phenol to extract would thus represent 50 per cent bark extract and 50 per cent phenol, excluding the contribution to total weight that comes from formaldehyde, sodium hydroxide, and fillers. For practical purposes, the weight ratio of polymethylolphenol to extract, both of these reagents being present in partial salt forms that are alkaline in pH, is of significance to

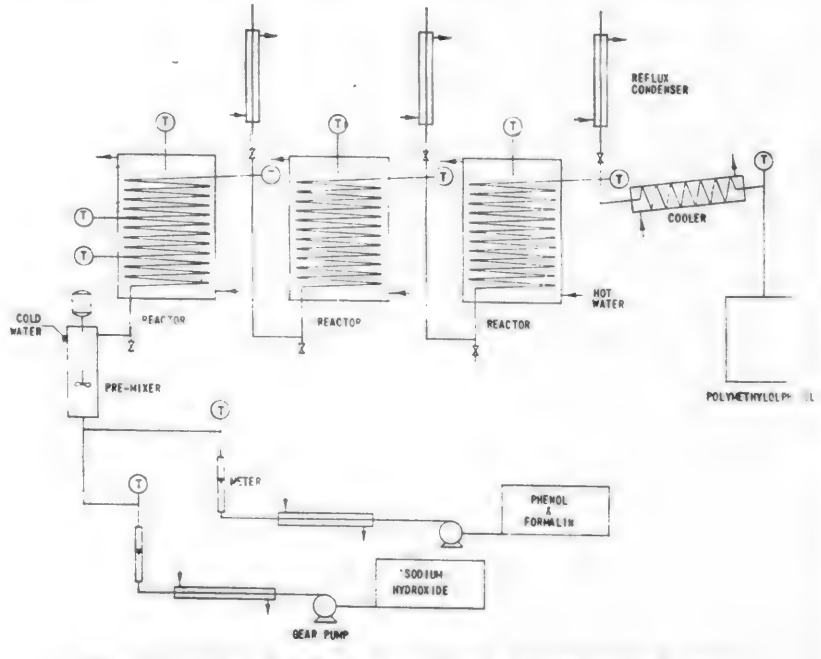


Fig. 1.—Schematic diagram of the continuous polymethylolphenol process.

Table 4.—EFFECT OF ADHESIVE FORMULATION VARIABLES ON ADHESIVE VISCOSITY AND BONDING PROPERTIES

Mole ratio Phenol:CH_2O: NaOH used for polymethylol-phenol (PMP) reagent	Adhesive solids composition (excluding filler)			Liquid adhesive properties (no filler added)			Average plywood test results[1]		
							Knife test	Boiling water test	
	Dry basis bark extract %	Ratio PMP: ext.	Ratio Phenol: ext.	Adhesive solution visc., poises at 25°C.	% T.S.[2] as used	pH	% Wood failure	Wet shear strength	% Wood failure
2.1:0.75	65.2	0.534	0.31	9.8	37.5	10.4	90	161	85
	48.5	1.064	0.62	2.3	36.5	10.6	90	157	90
2.6:0.75	68.5	0.46	0.25	1000+[3]	36.5	9.8	93	211	83
2.6:0.75	64.5	0.552	0.30	1000+[3]	37.0	9.85	94	224	93
2.9:0.75	60.9	0.642	0.35	1000+[3]	36.0	9.9	95	190	91
2.6:0.75	58.4	0.712	0.39	450[3]	37.0	10.5	96	189	93
2.6:0.75	47.5	1.105	0.6	30[3]	40.0	10.6	95	200	95
2.6:0.75	40.8	1.450	0.8	9	40.0	10.7	95	214	92
2.6:0.75	35.2	1.84	1.0	4	40.0	10.8	No test		
2.9:1.0	76.8	0.302	0.15	1000+	38.0	10.2	90	77	72
2.9:1.0	66.5	0.504	0.25	800	38.0	10.4	92	102	88

[1]Adhesive solids were extended 20% with walnut shell flour. Glue spread: 75 lbs./Mdgl. (Thousand square feet-double glue line). Schedule: ¼-inch 3-ply pressed with platens at 140°C. (285°F.) and 150 psi for 10 minutes.
[2]T.S. = total adhesive resin solids.
[3]Viscosity (Brookfield viscometer) unusually high due to extract variable. Process control results in viscosities in the order of 8 to 800 poises in this series.

Table 5.—EFFECT OF POLYMETHYLOLPHENOL MOLECULAR WEIGHT ON ADHESIVE VISCOSITY AND BONDING PROPERTIES

Polymethylolphenol reagent[1]		Adhesvie formulation with 53% bark extract in solids[2]		Average plywood tests[4]		
		Viscosity, Poises at 25°C.		Knife test	Boiling water test[5]	
Combined CH_2O Moles/ Mole of phenol	Solution viscosity, Poises at 25° C.	Solution 40% T.S. (unextended)	Glue mix,[3] 45% T.S.	% Wood failure	Wet shear strength	% Wood failure
2.34	0.805	11.0	23.0	91	169	97
2.28	2.10	17.0	60.5	91	146	85
2.24	4.4	34.0	140	92	120	82
2.20	9.8	60.0	440	89	118	77

[1]Bottom section of Table 4.
[2]0.5 ratio phenol to extract.
[3]20% extension with Furafil S-100.
[4]Veneer: 0.1 inch Douglas fir veneer 2-3% H_2O. Glue spread: 55 Lbs./Mdgl. Assembly Time: 10 minutes. Schedule: Two ¼-inch 3-ply. Platens 140°C. (285°F.). Pressure 175 psi.
[5]40 shear specimens (8 panels).

Table 6.—PLYWOOD MILL TEST.

Plywood construction	Glue spread, lbs. Mdgl.	Estimated assembly time, Min.	Press schedule: No. of panels per opening	Press schedule: Time, min.	Press schedule: Platen temp., °F.	Average boiling water test results: Laboratory[1] Wet shear strength, psi	Laboratory[1] % Wood failure	Independent test Wet shear strength, psi	Independent test % Wood failure
5/16-Inch 80 Panels Two Press Loads	59	15.5	2	5	300	173	92	118	92
	59	10	2	5	300	133	91	120	95
	59	5	2	5	300	227	76	130	72
	59	4	2	5	300	186	91	122	91
	57	10	2	6	300	180	91	110	100
	57	5	2	6	300	184	74	110	46
	57	5	2	6	300	173	93	120	99
	57	15-20	2	6	300	167	53	104	78
	Average					178	83	117	84.1
	Average knife tests: 86.5% wood failure								
9/16-Inch 60 Panels Three Press Loads	57	14.75	1	5.5	300	146[2]	79	76[2]	100
	57	9.75	1	5.5	300	130	95	72	100
	57	7.75	1	5.5	300	108	95	76	97
	57	4.25	1	5.5	300	146	89	90	88
	57	18.5	1	6.0	300	84	89	82	88
	57	16.5	1	6.0	300	172	82	92	92
	57	14.0	1	6.0	300	159	94	94	100
	57	10.5	1	6.0	300	139	89	86	74
	Average					136	89	84	93.6
	Average knife tests: 91.5% wood failure in core.								
13/16-Inch 40 Panels Two Press Loads	60	20	1	10	300	51[2]	66	62[2]	94
	60	12.5	1	10	300	66	68	66	87
	60	11.0	1	10	300	81	76	62	75
	60	9.0	1	10	300	73	62	70	80
	60	15	1	10	300	50	66	64	69
	60	15	1	10	300	70	66	60	98
	60	25	1	10	300	65	69	78	69
	60	25	1	10	300	68	61	54	96
	Average					66	69	64.5	83.5
	Average knife tests: 63.8% wood failure in core.								

[1]Represents 30 test specimens per panel. Douglas-fir veneer moisture = 2-4%. Pressing pressure 180 psi. All panels were hot stacked.
[2]Tests results fo 9/16-inch and 13/16-inch are for core bonds only.

cost calculations and is also given in Table 4. The plywood test results of Table 4 reflect adequate or excess curing time, and are pertinent only to adhesive formulation variables due to different amounts of a cross-linking agent being mixed with a particular bark extract. It can then be concluded that, providing certain viscosity handicaps (1000+ poises) could be overcome, an adhesive containing about 65 per cent bark extract will yield plywood that comes within the bonding quality limits for exterior plywood as specified by the DFPA. A consideration of pressing schedules and reduction of curing time requirements to meet commercial production requirements follows.

Glue bond formation in the case of phenolic resins in general requires some source of energy for "thermosetting" or otherwise completing a polymerization reaction. The economics of certain aspects of the phenolic resin-plywood industry seem to hinge on reducing curing-time requirements for glue bonds to a minimum to satisfy the greatest press production capacity.

Selection of a bark extract-polymethylolphenol adhesive containing about 55 to 65 per cent bark extract was based on curing-time requirements. Polymethylolphenol by itself is a slow-curing adhesive since it requires much energy for polymerization with elimination of formaldehyde and water before the final insoluble, infusible state is reached. However, the principle of using cross-linking agents to set up synthetic polymers has been applied in many fields of polymer chemistry and in fast-curing phenolic plywood adhesives. This operation requires the proper balance of physical properties with formulation at maximum molecular weight so that very little energy is spent in cross-linking to the desired high-strength, boilproof adhesive bond.

In the present case, excess polymethylolphenol increases curing time requirements, whereas excess bark extract results in loss of strength or additional curing time to make full use of all available crosslinking potential. A formulation containing 60 per cent bark extract (HT-120) and 40 per cent polymethylolphenol reagent seemed to provide the best balance of properties.

Polymethylolphenol Molecular Weight vs. Cross-linking Efficiency: Trimethylolphenol (monomer) might be considered as having the maximum cross-linking capacity of any member of the polymethylolphenol system. Some evidence was obtained that low molecular weight condensates such as dimers, trimers, and so forth, were bet-

ter cross-linking agents than is trimethylolphenol. This may be due to factors of steric hindrance, mobility, molecular size, and so forth. As polymerization continues (Table 3), cross-linking potential is decreased and the polymethylolphenol reagent becomes less efficient in the desired reaction with the bark extract. Molecular size is increased as indicated by viscosity increase. Observed data is presented in Table 5. In theory and on an average, a combined formaldehyde mole ratio of 2.5 CH_2O:phenol could be said to represent a dimer and at 2.2 the average is more like a pentamer. The effect on adhesive viscosity is notable, and was fairly severe in a glue mix that was extended with 20 per cent filler based on adhesive solution solids. Plywood tests in Table 5 reflect near-minimum curing time requirements and not optimum or excess cure time. A curing time of 6 minutes for two ¼-inch 3-ply assemblies at a platen temperature of 140° C. (285° F.) gave passable results only when the average molecular weight of the phenolic reagent was fairly low. Equality in curing-time requirements was also obtained by reducing the bark extract content in the formulation when the polymethylolphenol reagent was more highly condensed. In fact, such a formulation permits somewhat greater extension with fillers at the expense of lower utilization of bark extract for equal bonding quality.

Plywood Mill Trial: A trial run of commercial plywood was made under production conditions. An adhesive and a pressing schedule resulting from laboratory experience was used, and the final run was closely supervised by both mill and laboratory. Table 6 is fairly self-explanatory to those acquainted with plywood production. The adhesive mix contained a blend of 57.6 per cent bark extract and 42.4 per cent polymethylolphenol solids made up to 40 per cent total solids, and had a viscosity of 8 poises at 25° C. Furafil S-100 was added at 8 pounds per 100 pounds of 40 per cent T.S. liquid adhesive.

Unfortunately, the glue mix contained 44 per cent T.S., this being somewhat low. Solids at 46 to 47 per cent would have given improved bonding based on laboratory results. Excess water in veneer or adhesive generally requires additional curing time. None of the 260 (4 by 8 foot) panels produced in nine press loads of various constructions was observed to blow, nor was the glue spreading, assembly, press loading, hot stacking, and so forth, abnormal in any respect. An independent test on samples of plywood was requested for comparison with plywood evaluation conducted in our laboratory.

Quality Control for Bark Extracts for Use as Resin Intermediates: From the foregoing description and discussion, it is fairly obvious that utilization of hemlock bark and other bark raw materials in the production of highly reactive polyphenolic products requires careful control of the extraction and subsequent processing of liquors to yield a product with uniform viscosity and reactivity properties. Considerable effort was expended in developing reaction conditions that would yield reproducibly uniform characteristics in the desired end-use application.

In the case of exterior plywood adhesives, the final criterion of acceptability of products of commercial unit production was actual testing of routine samples in adhesive formulation and plywood. Tests of a simpler nature were based on relative viscosity measurements. Chemical composition was also controlled to specifications by routine analysis. Large-scale production actually presented few quality control problems once initial engineering difficulties were solved.

Conclusion

It has been shown that an exterior-type plywood adhesive meeting present commercial requirements can be made from a hemlock bark extract and a polymethylolphenol containing a high proportion of reactive methylol groups. In the resulting adhesive, a large portion of the expensive phenol normally required in an exterior-type plywood adhesive is replaced by the low-cost bark product. It is hoped that use of this adhesive may prove beneficial to the plywood industry in cutting costs and expanding the market for exterior-type plywood.

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Discussion

G. G. Marra (Washington State Institute of Technology): If this is a proper question, could you tell us what yield of adhesive is obtained per ton of bark?

Mr. Herrick: Although I can't give you any figure, the yield is sufficiently high to insure that HT-120 can be produced in commercial quantities. We consider the economics of the process to be favorable.

A. S. Gregory (Weyerhaeuser Timber Co.): Is Rayonier selling this product on a commercial scale, and if so, what is the selling price?

Mr. Herrick: HT-120 has been produced on a pilot-plant scale and supplied in quantities for plant trials. It is being sold at 10 cents per pound

A SURVEY OF METHODS OF Measuring Smoothness of Wood[1]

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Various methods of photographing wood surfaces are described to compare the smoothness of wood treated in several ways by comparing light reflectivity. Instruments used in analyzing the smoothness of metal surfaces are described. These were used for comparing wood surfaces refined by planing, sanding, and microsealing. Profiles of the surfaces obtained are presented in which the height of irregularities is magnified 1000 times and the width 100 times. Fine grooves from finish-sanding are revealed as valleys between high ridges. Flattening such ridges by microsealing is discussed.

IN DISCUSSING THE SUBJECT of wood finishing, it is customary to assume that the wood as received in the finishing room has been sanded to obtain a smooth surface. The process of finishing starts from the sanded surface. In the case of finishes on hardwood, it is customary to fill the pores of the wood as the first step to further improve the smoothness of the finish. The wood surface may also be given a stain. Several coats of lacquer or varnish may then be applied, each coat being given a light sanding or rubbing until the desired elegance is obtained.

The art of finishing wood, as commercially conceived of, therefore refers to the sequence of steps taken by the wood finisher, and the combination of materials he uses for application to the wood surface. The purpose of this paper is to describe various means for measuring surface smoothness prior to the application of finishing materials. Methods are now in use in the wood processing industry that go beyond sanding in refining the wood surface preparatory to finishing. A study of the surface of wood refined by new techniques has led to the necessity for understanding the effect of various surface treatments in greater detail than has been commercially regarded as necessary heretofore.

It has been found that instruments of great refinement, developed for studying surface finishes on metal, can also be used in studying the surfaces of wood. The present paper describes such instruments and their use, and the results obtained in applying techniques for their use to the study of wood surfaces. Methods were explored for comparing wood surfaces polished with fine sandpaper, with similar surfaces refined by new mechanical means. The study is based upon expermental work conducted in the Elmendorf Laboratory. Some of the work was, however, done abroad. We had the assistance of two leading research laboratories in Germany, namely the Forest Products Laboratory[2] at the University of Munich, headed by Professor F. Kollmann, and the Wood Research Laboratory[3] at Karlsruhe, headed by Dr. Eric Plath. We also received generous assistance from the Engis Equipment Company of Chicago in the use of the Talysurf instrument developed in England for measuring and recording magnified contours of surfaces.

Methods of Preparing Wood Surfaces for Finishes

Sawing, Planing, Sanding: Compared to the surface obtained by means of an adze, the sawed surface is relatively smooth. In recent years, the use of wood boards from which the saw marks have not been removed has found favor in board-and-batten construction.

Planing a sawed surface represents the next step in refining a wood surface for paint or enamel finishes. Interior trim in house construction is generally planed.

The third step in refining the surface in preparation for finishes is sanding. This may be done by means of various types of sanding machinery, such as vibrating sanders, belt sanders, or drum sanders. The fineness of the

[1] Presented at Session XII, Wood Finishing, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

The Authors: Armin Elmendorf holds BS and MS degrees in mechanical engineering from the University of Wisconsin. He was formerly an instructor at the U. of Wis. and an engineer in forest products at the U. S. Forest Products Laboratory.

T. W. Vaughan is a graduate of Illinois Institute of Technology. He has been associated with Elmendorf Research since 1944.

[2] Institut für Holzforschung und Holztechnik, Der Universität München.

[3] Forschungsinstitut für Holzwerkstoffe und Holzleime.

Fig. 1.—Glossimeter test. The panel on the right is birch plywood sanded with 4/0 sandpaper. The panel on the left is a similar panel also sanded, and then microsealed.

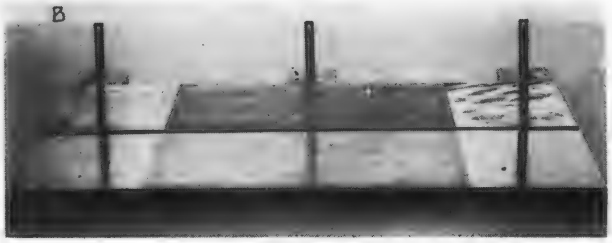

Fig. 2.—Shadow test, birch boards. The board in the background was sanded, after which one end was given a coat of lacquer, and the opposite end a coat of varnish. The board in the foreground was similarly sanded, and then microsealed, followed by lacquering and varnishing the ends.

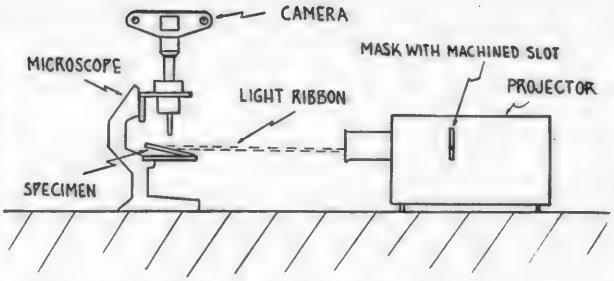

Fig. 3.—Light ribbon test. A thin ribbon of light from a projector impinges upon the specimen at an acute angle. The reflected light is photographed as a broad line with a camera placed over the eye-piece of the microscope.

grit used on the sandpaper determines the degree of surface refinement. A panel may be given successive sandings with progessively finer grit until the last stage of polish sanding is reached. Polishing may be done with 6/0 sandpaper.

Buffing, Burnishing, Microsealing: Buffing, as commercially practiced in the metal industry by means of a buffing wheel, is not extensively used in the woodworking industry because of the danger of removing wood substance that may be softer than neighboring wood.

Burnishing is infrequently resorted to because of the difficulty of retaining a flat surface, and the danger of discloration resulting from "burning".

Of the various treatments for refining the surface after sanding, the microseal process (1) [4] seems to have gained the greatest acceptance. A well-known method of microsealing wood surfaces consists in frictionally heating the wood surface by means of a belt operating at high speed. The belt is surfaced with cork granules. In this operation, the temperature of the extreme surface is suddenly raised to a temperature adequate to soften the surface fibers and their natural binders, without appreciably affecting fibers below the surface. Sudden heating of this type appears to introduce considerable flattening of the surface with improvement of light reflectivity. Very little substance is removed in the microseal process.

The addition of a thin coat of a dilute synthetic resin plasticizer further improves the flattening of the surface. All the illustrations of this paper that involve microsealing (except Fig. 7) show the results on surfaces that had been so treated.

Methods of Photographing Wood Surfaces

Glossimeter: Fig. 1 shows the apparatus sometimes used in the study of wood finishes for comparing surfaces finished in various ways. The apparatus consists of a glass plate upon which thin strips of metal foil have been mounted in the form of a grid. The test specimens are placed before this grid, which is tilted at an appropriate angle, and light from a lamp in back of the grid is allowed to pass through the glass, thereby throwing shadows on the panels below. Fig. 1 compares the effect obtained with the microseal treatment, following sanding with 4/0 sandpaper, on birch plywood. Although the sanded panel feels very smooth to the touch, the surface, when seen under a microscope, has nevertheless been mutilated in the sense that many surface fibers have been torn, with the result that light striking the surface is diffused. The same surface given the miscroseal treatment shows substantially greater light reflectivity or gloss.

Shadow Test: In the shadow test, the wood specimens are placed in front of narrow posts, which throw a shadow across the specimen. As will be noted from Fig. 2, one coat of lacquer or varnish applied to a hardwood (or softwood) surface that has been sanded, results in a "starved" finish. By the additional step of microsealing the surface, a single coat of lacquer or varnish results in a very uniform finish.

Light Ribbon Test: The possibility of discovering differences in surface contours was explored by the use of a thin flat ribbon of light reflected from the specimen and observed through a microscope. By placing a camera over the eye-piece of the microscope, a photographic record in the form of a slightly jagged light line was obtained. The slit through which the light passed was very narrow, but it was not narrow enough to obtain an effective line of light on the specimen. While this method of testing would appear to be practical for comparing wood surfaces treated in different ways, it proved unsatisfactory for detecting minute differences in elevation on the surface of wood refined beyond sanding. Fig. 3 shows the apparatus used for the light ribbon test.

Highlighting Test: By placing a source of light at an acute angle to a sanded wood surface, so that the light streams across the grain, and then photographing the surface from above with a sharp focus, it became possible to photograph very small ridges and depressions in the surface of the wood. A good camera can pick up grooves cut by 4/0 sandpaper, as may be seen from Fig. 4 (bottom). The top of the illustration shows the same area after it had been given the microseal treatment. While this test is strictly qualitative, it does reveal differences in surface smoothness as evidenced by the fact that the samples further leveled off by means of the microseal process show no highlighting.

Fig. 5 shows two sections cut from the same birch plywood panel. This test differs from that shown in Fig. 4 in that the light beam is in the direction of the wood grain instead of across the grain. The photographs in this case were taken through a micro-

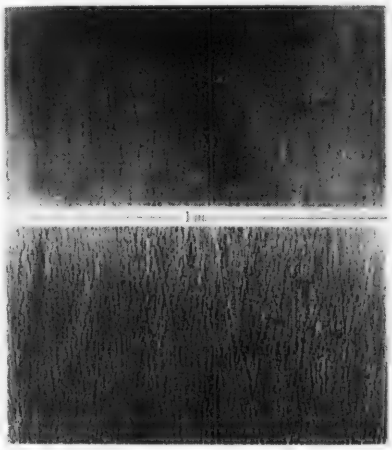

Fig. 4.—Highlighting test. The lower photo shows a section of a gum plywood panel that had been sanded with 4/0 sandpaper. The upper photo shows the same area after it had been given the microseal treatment.

[4] Numbers in parentheses refer to the Literature Cited at the end of this paper.

Fig. 6.—Microphotograph of a cross section of birch plywood at the edge of the panel, magnified 150x. The panel had been sanded with 4/0 sandpaper.

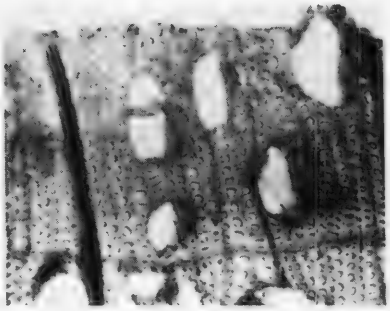

Fig. 7.—Microphotograph of a cross section of birch plywood at the edge of the panel. The panel had been sanded and then microsealed.

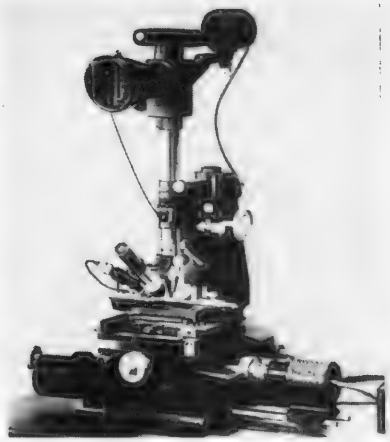

Fig. 8.—Forster apparatus for measuring and recording magnified surface contours on film.

scope. The specks of light scattered about the surface in the top photograph show minute fiber fragments resulting from sanding. Such fragments are largely flattened out or removed by the microseal process, as shown in the lower photograph.

Microphotographs of Wood Sections at the Surface: Fig. 6 shows a microphotograph of a section of a birch plywood panel at the surface that had been sanded with 4/0 sandpaper. The photograph was taken at the Forschungs institut für Holzwerkstoffe und Holzleime. It shows considerable mutilation of the surface fibers, particularly those adjacent to vessels.

Fig 7 shows a microphotograph of the edge of a birch panel also sanded with 4/0 sandpaper, and then given a microseal treatment. The section shown in the photograph is about 1/40 inch wide.

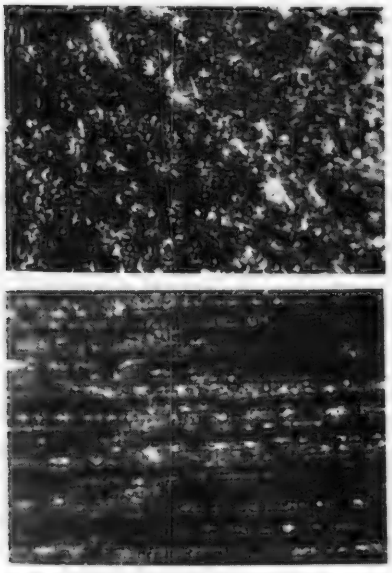

Fig. 5.—Highlighting test. The upper photo shows fibers fractured by sanding on the surface of a birch plywood panel, as seen through a microscope. The lower photo shows a similar area after sanding and then microsealing.

Measuring Panel Waviness

By Means of a Micrometer: Marian and Suchsland (2), in their work at the Swedish Forest Products Research Laboratory, devised apparatus for measuring warping and waviness of thick panels used in the furniture industry. Their measurements were made by means of a micrometer screw resting on a ground glass plate. The specimen was supported on four supports over the ground glass plate, measurements being made of the distance between the plate and the specimen at specified intervals. The traveling micrometer dial permitted an accuracy of 0.01 mm, it being deemed that a higher accuracy was not necessary for the information desired. They found that, if the deviations in the surface were measured both before and after changes in moisture content of the panel, unevenness of the surface resulting from changes of moisture content could be detected in the contour line of the surface. The investigators were not concerned with comparisons of scratch marks resulting from sanding the surface, or measurements of minute depressions resulting from pores at the surface of face veneers. The authors point out that highly polishd surfaces of wood will show very small irregularities or unevenness that were not observable before polishing.

By Means of an Amplifier-Recorder: R. A. Hann (3), in his work at the University of Michigan, devised apparatus involving strain gauges so connected that vertical deflections are magnified by means of an amplifier-recorder. The probe of the apparatus used touches the surfaces being studied. It consists of a steel ball 1/4 inch in diameter, the size of the ball being considered satisfactory for the studies of the wood panel surfaces investigated, which included machined surfaces and particle boards. The amplifier-recorder magnifies the strain in the pick-up head, and records it on a moving paper chart. The speed of the chart and the amplifier can be adjusted to vary the ratio of the vertical to horizontal magnification.

Hann found it possible to measure telegraphing in certain types of particle boards. He found that the apparatus detected differences in surface contours resulting from humidification.

The size of the steel ball used for probing the surface was obviously far too great to record minute scratches produced by sandpaper.

Instruments for Magnifying and Recording Surface Profiles

The measurement of surface irregularities resulting from cutting or grinding metal surfaces is a refined art, and various instruments of great precision have been devised for this purpose. Of these instruments, two have received considerable prominence, one in Germany, and the other in England.

The former, known as the Forster apparatus manufactured by Ernst Leitz, is used in the Forest Products Laboratory at the University of Munich, and was used in the analysis of some of the wood sections prepared in the U. S. for the tests. The latter is the Talysurf instrument manufactured by Taylor, Taylor & Hobson.

Considerable technical literature is available describing the operation of both instruments and their use for analyzing metal surfaces. The papers describing the Forster apparatus are primarily German dissertations (4,5,-6). The Talysurf instrument is well described in two papers by R. E. Reason(7,8).

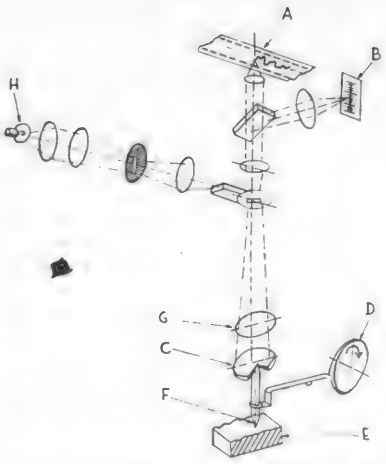

Fig. 9.—Schematic construction of the Forster apparatus: *A*, film; *B*, ground glass viewer; *C*, tilting mirror; *D*, oscillating mechanism; *E*, test specimen; *F*, stylus; *G*, lens; *H*, light source.

Forster Instrument: Fig. 8 shows the Forster instrument used abroad, and Fig. 9 shows a schematic drawing of this instrument. In this apparatus, the test specimen is moved sideways by means of a motor at a speed of from 1 to 5 mm per minute. It moves under an oscillating stylus, which consists of a sapphire needle with a tip whose radius may be from 5 to 10 microns when used on metal, but must be larger, about 50 to 60 microns, when the apparatus is used for testing wood. The needle moves up and down at high speed, generally from 50 to 100 times per second. The record of the surface contour is photographed on the film shown in *A* of Fig. 9. A tilting mirror reflects a beam of light as the stylus oscillates, and a record of the oscillation is recorded photographically on the film shown at *A*. The pressure on the needle ranges from 0.6 to 1.0 g. Magnification as recorded on the film is up to 1000x in the vertical direction, and from 20x to 100x in the horizontal direction. When a vertical magnification of 1000x is used, the range of measureable differences is 24 microns. With a needle that has a radius of 10 microns, the width of the groove that can be measured must exceed 5 microns.

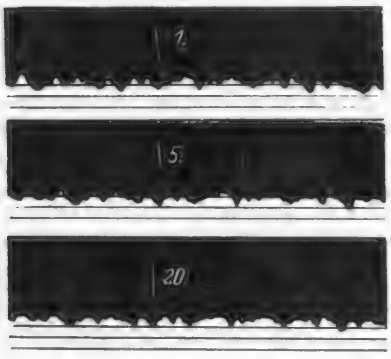

Fig. 10.—Tests to determine the reproducibility of the contours obtained with the Forster apparatus. The lowest contour shows the result after 20 passes across the grain of a piece of fir at a moisture content of 35 per cent. Compare this with the top contour obtained in the first pass.

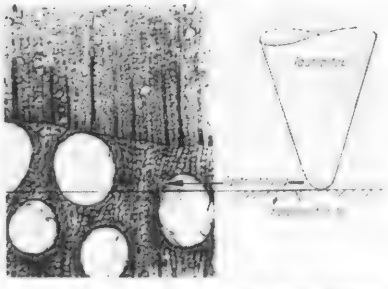

Fig. 11.—Comparative size of the sapphire stylus of the Forster apparatus and the vessels of a section of oak. The radius of this stylus was 60 microns.

The question is sometimes raised as to whether successive passes over the same width of test area produces the same contour. Ehlers (9) made tests in this connection, passing the stylus across a given span 20 times. The results of these tests are shown in Fig. 10, from which it will be noted that the contours are reproducible.

Fig. 11 shows the relative size of the stylus used by Ehlers when compared with the size of the vessels in a cross-section of oak.

Fig. 12 A shows a diagrammatic cross section of three pores slit near the surface of the wood, one with the center above the surface, the second with the center at the surface, and the third with the center below the surface. When the magnification in the vertical direction is the same as in the horizontal direction, the contour shown in *B* is the result. When the vertical magnification is 10x as great as the horizontal, the contour shown in *C* is the result. It must be noted, therefore, that the contour recorded on the film of the Forster apparatus does not represent a true picture of the proportions of a depression or groove, such as a pore. It is important that this fact be kept in mind when examining the results obtained with this instrument. The contours shown are those for a stylus point with a radius of 55 microns. The pore diameter assumed in the diagram is 0.007 inch, or 175 microns. Relative size and shape of the stylus compared with the pore is shown in Fig. 13.

Talysurf Instrument. The Talysurf instrument (10) for measuring surface irregularities, such as that of polished wood, like the Forster instrument, depends for its accuracy upon the sharpness of its stylus. The nosepiece of the instrument is shown in the photograph of Fig. 14, and a cross section of the nosepiece will be seen in Fig. 15. The stylus has the form of a four-sided 90° diamond pyramid. At its point, the diamond tip is approximately 0.0001 inch wide. The relative sizes and shapes of the diamond tip of the Talysurf stylus, and the sapphire tip of the Forster instrument, may be seen in Fig. 13.

The stylus and the pen are mechanically separated, and the power output of the stylus is amplified. Ink has been avoided, and the marking is electrical. The tape upon which both the vertical and horizontal movement of the stylus are recorded may be seen in Fig. 14, which also shows a plywood panel in position under the stylus. The Stylus moves across the grain of the wood for about ⅜ inch, and the horizontal magnification of the horizontal movement may be either 20x or 100x. The vertical magnification may range from 1000x to 50,000x. In studying the wood surfaces, a vertical magnification of 1000x was used.

Minute scratches, such as those produced by fine sandpaper, being very much larger than the tip of the Talysurf stylus, are, therefore, recorded by the instrument. The vertical movement recorded by the apparatus is the movement of the tip of the stylus relative to the plane of the sliding shoe shown in Fig. 15. The length of the shoe is about ¼ inch, so that it spans a

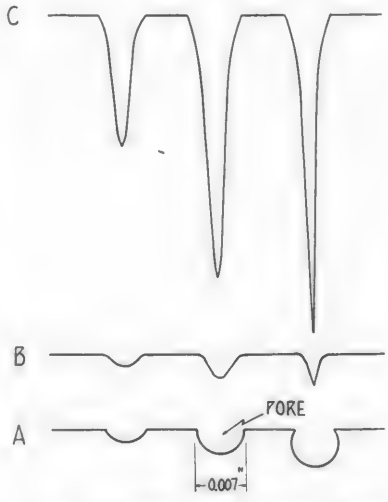

Fig. 12.—Approximate contours obtainable with the Forster apparatus when a sapphire stylus with a radius of 55 microns is used. *A*, section through three pores of different depth, radius 85 microns; *B*, contour obtained when the vertical and horizontal magnifications are the same; *C*, approximate contour when the ratio of the vertical to the horizontal magnification is 10:1. (See Fig. 13 for the relative size of the tip of the stylus and the pore transversed.)

series of ridges. Operators of the instrument report that the pressure of the stylus on the surface ranges from a few milligrams to 100 milligrams. In other words, the pressure is generally less than 1/10 g. Examination of the path traversed by the stylus on wood by means of a magnifying lens revealed no evidence of any surface damage or gouging.

As the diamond point of the stylus moves across a pore, and the tip moves down into the pore and out again, the pen records the contour of the pore as shown in *C* of Fig. 16. In *C* the ratio of vertical to horizontal magnification is as 10:1. When the vertical and horizontal magnification are the same, a diagram similar to that shown in *B* is the result. It will be seen, therefore, that the diagram recorded on the tape does not conform to the exact shape of minute depressions in the surface traversed. Most surface irregularities do not have the sharp outline of the split pore shown in *A*. The flanking angle of depressions traversed in a sanded wood surface are generally less than the 45° of the side of the pyramidal diamond point. In studying the graphs on the tape, it must always be borne in mind that the depth of the grooves shown in the graph greatly exaggerates the actual depth, and that the contour of the groove does not represent the actual contour in respect to ratio of depth to width.

Reference to Figs. 12 and 16 will show that, when the ratio vertical to horizontal magnification is 10:1, the diagram drawn by the Talysurf instrument is very similar to that drawn by the Forster instrument.

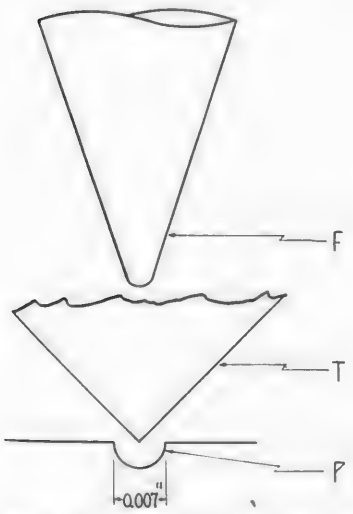

Fig. 13.—Comparative sizes and shapes of a pore with a diameter of 175 microns, and the stylus tips of the Forster (*F*) and Talysurf (*T*) instruments.

Results of Surface Profile Measurements

Profiles Obtained with the Forster Instrument: Typical contours obtained with the Forster instrument by Ehlers (9) in exploring the surfaces of beech boards that were sawed, planed, or sanded, are shown in Fig. 17. The graphs show the wood with horizontal lines, the air above being the dark area Contour *A* shows the result obtained when a beech board is sawed with a coarse gang saw, and *B* the result when a fine gang saw was used. Contour *C* shows the result of sawing with a band saw, and *D* with a circular saw. *E* shows the contour of a sanded beech surface, and *F* the contour of a planed surface produced by sharp knives. All of the contours except *E* and *F* follow the grain of the wood. Contours *E* and *F* show the result when the stylus moves across the grain of the wood.

Figs. 18 and 19 show typical contours obtained at the University of Munich on redwood and walnut lumber. *R–4–D* is the contour of redwood lumber sanded with 4/0 sandpaper, and *R–3–C* the same wood that was sanded and then given a microseal treatment. Typical contours of a porous wood, namely walnut, are shown in Fig. 19 in which *W–3–D* shows the contour of a sanded surface, and *W–2–C* the contour of a walnut board that had been sanded and then microsealed. In the diagrams of Figs. 18 and 19, the vertical magnification was 200x, and the horizontal 20x, so that the ratio of vertical to horizontal was 10:1. Similarity, may be noted between the shape of the magnified pore grooves in these diagrams taken from actual specimens, and the magnified grooves of theoretical cylindrical pores illustrated in Fig. 12. Fig. 18 also shows the relative width of the grooves produced by sanding, compared with the distance between two ridges of summerwood.

Fig. 19 shows the relative size of the grooves produced by sanding walnut in comparison with the size of the pores. The microseal treatment obviously has flattened the ridges resulting from sanding, both in the redwood and walnut. It will be noted in this connection that the vertical magnification is only one-fifth of that of the Talysurf instrument. In all the diagrams of Figs. 18 and 19, the light portion shaded with horizontal lines represents the wood.

Profiles Obtained with the Talysurf Instrument: Inasmuch as considerable interest exists in the problem of telegraphing in particle boards, and since telegraphing is largely determined by the size of surface particles,

Fig. 14.—The Talysurf instrument for recording surface contours, showing the nosepiece containing the stylus over a plywood panel. The graph is recorded on the tape shown at the right.

contour tests were made on commercial particle boards with the Talysurf instrument. The graph of a typical commercial particle board used as a core for the application of face veneers in the furniture industry is shown in *A* of Fig. 20. In this figure, the ratio

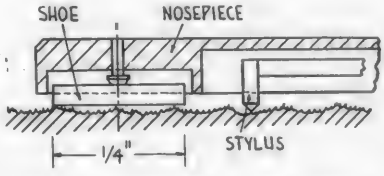

Fig. 15.—Nosepiece of the Talysurf instrument, showing the diamond-pointed stylus and the sliding shoe.

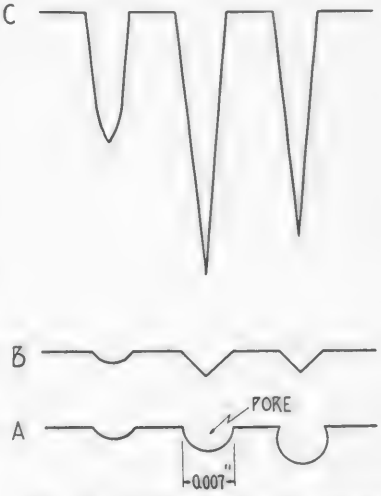

Fig. 16.—Approximate contours obtained with the Talysurf instrument when a diamond stylus with a 90° pyramidal point is used. Width of the tip is about 2.5 microns. *A*, section through three pores of different depth, radius of the pores about 85 microns; *B*, contour obtained when the vertical and horizontal magnifications are the same; *C*, approximate contour when the ratio of the vertical to horizontal magnification is 10:1. (See Fig. 13 for the relative size of the tip of the stylus and the pore traversed.)

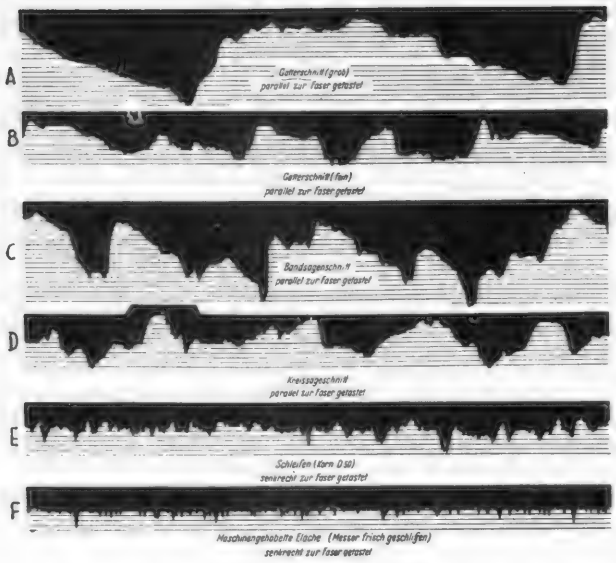

Fig. 17.—Surface profiles obtained with the Forster instrument on a flat-cut beech board surfaced in various ways (see text for description).

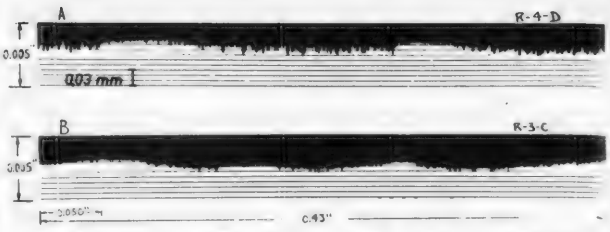

Fig. 18.—Surface profiles obtained with the Forster instrument on redwood lumber that had been: *A*, sanded with 4/0 sandpaper; *B*, sanded with 4/0 sandpaper and then microsealed. Ratio of vertical to horizontal magnification is 10:1.

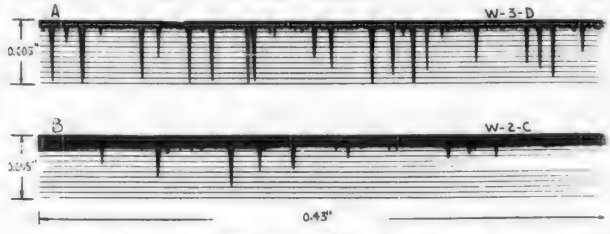

Fig. 19.—Surface profiles obtained with the Forster instrument on walnut lumber that had been: *A*, sanded with 4/0 sandpaper *B*, sanded with 4/0 sandpaper and then microsealed. Ratio of vertical to horizontal magnification is 10:1.

of vertical to horizontal magnification is 50:1.

Fig. 20 *B* shows the profile of a new type of particle board produced in the pilot plant of Elmendorf Research, the board being intended for wood-grain finishes as used in radio and television cabinets. The board in this case had the same density as the commercial board whose graph is shown in section *A*. The distance between the horizontal lines in this diagram represents a vertical displacement of 0.0001 inch.

Fig. 21 *A* shows the profile of a birch board that had been sanded with 4/0 sandpaper, and *B* shows a similar specimen cut from the same board that had been sanded and microsealed.

Fig. 22 shows the profiles of two specimens of walnut, diagram *A* being that of a sanded surface, and diagram *B* that of a similar specimen cut from the same board, in which the surface was both sanded and microsealed. Fig. 23 shows the profiles of a redwood board, *A* being the profile of the sanded surface, and *B* the profile of a surface that had been sanded and microsealed.

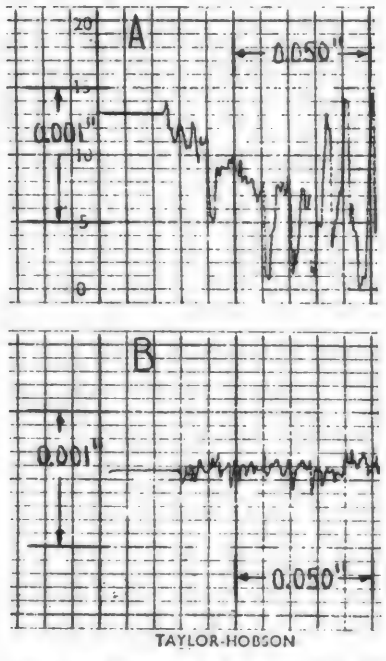

Fig. 20.—Surface profiles obtained with the Talysurf instrument on particle boards. *A*, commercial core board with fine surface particles used for veneering in the furniture industry; *B*, Elmendorf particle board developed for wood-grain finishes. Board has same density as the commercial product shown in *A*.

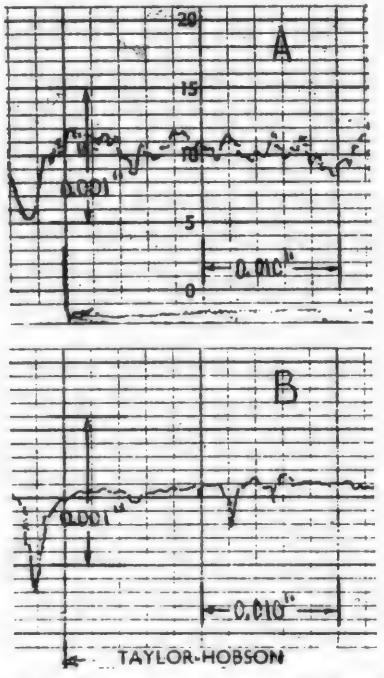

Fig. 21.—Surface profiles obtained with the Talysurf instrument on birch lumber that had been: *A*, sanded with 4/0 sandpaper; *B*, sanded with 4/0 sandpaper and then microsealed. Ratio of vertical to horizontal magnification is 10:1.

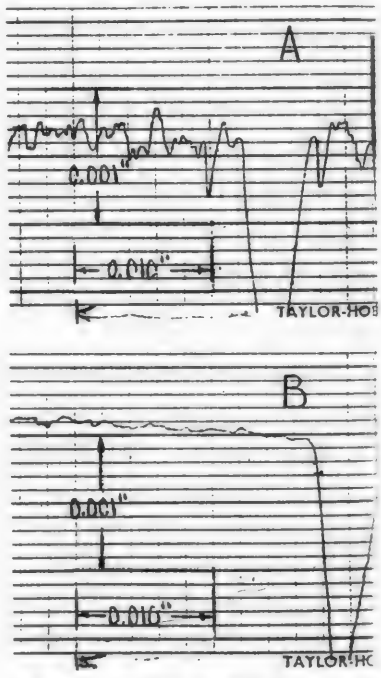

Fig. 22.—Surface profiles obtained wi the Talysurf instrument on walnut lumb that had been: *A*, sanded with 4/0 san paper; *B*, sanded with 4/0 sandpaper a then microsealed. Ratio of vertical to ho zontal magnification is 10:1.

It may be noted that the ratio of vertical to horizontal magnification in the Talysurf profiles is the same as that of the Forster instrument, namely 10:1, but the actual magnification in the Talysurf profiles is 5x that of the Forster profiles, hence the greater detail.

It was also noted that in the case of the Talysurf instrument, the recording pen would leave the tape sometimes when the stylus passed over a pore. This is readily understandable in view of the fact that the vertical magnification is 1000x, and that a pore 0.003 inch deep will be shown as a vertical distance of 3 inches on the tape. The width of the tape upon which the profile is recorded is 2 inches. The flattening out of the 4/0 sanded surface by the microseal treatment is obvious. The sanding ridges on redwood appear to be more pronounced that those on walnut or birch. The surface irregularities due to sanding, which are magnified 8x in Fig. 4, are magnified 1000x in Figs. 21, 22, and 23. The flattening obtained by the microseal treatment is evident in both the 8x and 1000x magnification.

Fig. 24 shows the profiles of redwood lumber obtained with the Talysurf in which the ratio of vertical to horizontal magnification was 50:1. The diagrams show the difference in the results obtained in sanding with various finenesses of sandpaper. All the panels were first sanded with coarse sandpaper, which was followed by successively finer papers as described in the illustrations. The deep grooves, being the result of sanding with coarse sandpaper, remain in large part, whereas the ridges are reduced in height with the finer sanding. The ridges are further reduced when the 6/0 sanding is replaced with microsealing, as will be noted in comparing diagram *D* and *C* in Fig. 24. It is customary in the commercial application of the microseal process to sand the wood, or panel, first with 4/0 sandpaper. There is relatively little difference between the surface resulting from 6/0 sandpaper and that obtained with 4/0, but a pronounced difference when the 6/0 is replaced with the microseal process.

Fig. 25 illustrates another method of comparing surface smoothness from surface profiles obtained with the Talysurf instrument. In this diagram, the peaks of the profile were connected with lines, as were the valleys. The areas enclosed between these lines have been shaded with diagnoal lines. The same procedure was followed with the profiles of surfaces that had been microsealed. It may be noted from these figures that there is a striking difference in area *A* of the profile of the sanded surface, compared to area *B* of the profile of the microsealed surface. It is this flattening out of the minute ridges that no doubt accounts for the greater reflectivity of the microsealed surface noted in the photographs of Figs. 1 and 2, and Figs. 4 and 5. The presence of ridges and torn fibers results in light diffusion. The greater the flattening of the minute ridges, the greater the gloss and the reflectivity.

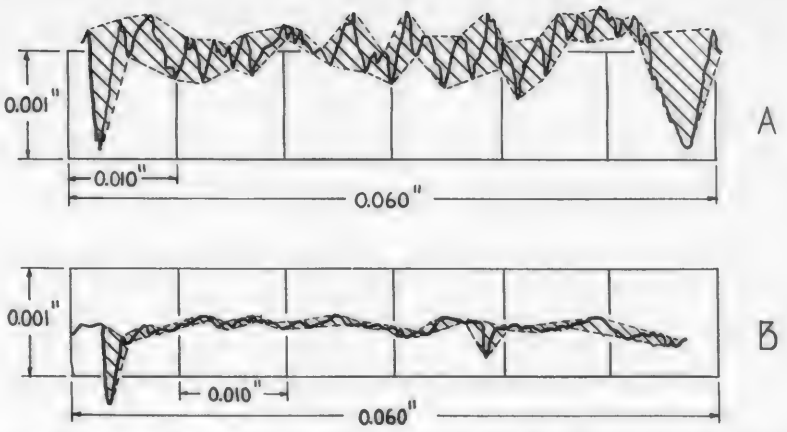

Fig. 25.—Surface profiles of birch plywood obtained with the Talysurf instrument. Surface smoothness measured by the reciprocal of the areas enclosed between the line connecting the crests and the line connecting the valleys of the contour line. Ratio of vertical to horizontal magnification is 10:1. A, sanded with 4/0 sandpaper, B, sanded with 4/0 sandpaper, then microsealed.

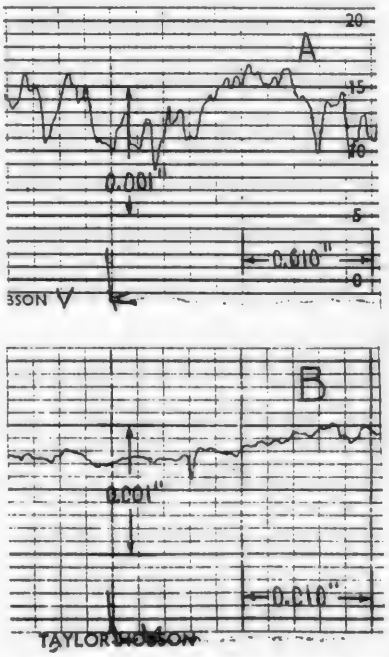

Fig. 23.—Surface profiles obtained with the Talysurf instrument on redwood lumber that had been: A, sanded with 4/0 sandpaper; B, sanded with 4/0 sandpaper and then microsealed. Ratio of vertical to horizontal magnification is 10:1.

Summary

The experimental studies made showed that refinements in the preparation of wood surfaces for finishes can be detected by several photographic procedures.

Two instruments used heretofore primarily for comparing metal surfaces were found to be useful for analyzing wood surfaces. Surface profiles of great precision were obtained with these instruments in which minute

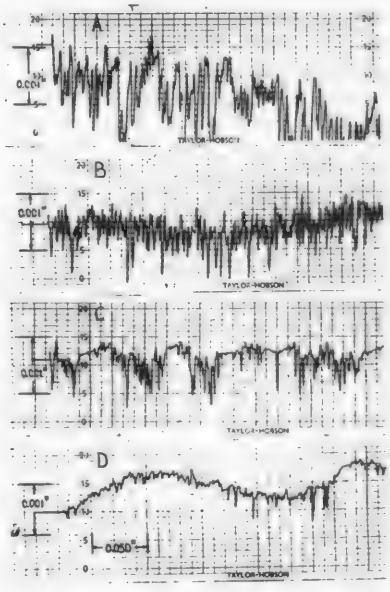

Fig. 24.—Surface profiles obtained with the Talysurf instrument on redwood lumber showing the effect of fineness of sandpaper. Ratio of vertical to horizontal magnification is 50:1. A, sanded with 1/0 sandpaper; B, sanded with 1/0, then 4/0 sandpaper; C, sanded with 1/0 then 4/0, then 6/0 sandpaper; D, sanded with 1/0, then 4/0 sandpaper, then microsealed.

ridges in a wood surface as fine as those resulting from finish sanding were magnified a thousand fold. Surfaces of several species of wood planed, sanded, and microsealed were analyzed. The ratio of vertical to horizontal magnification was varied.

The profiles obtained show the advantage of maximum vertical magnification. A ratio of vertical to horizontal magnification of 10:1 produced the most striking results. The data obtained revealed the differences between planing and sanding, and sanding followed by microsealing.

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Discussion

J. Milak (Connor Lumber and Land Co.): Does the Micro-Seal process offer any degree of dimensional stability of lieu of the conventional sealer?

Mr. Elmendorf: We have made no tests to determine any effect to Micro-Seal process may have on dimensional stability.

Mr. Milak: Your discussion and illustrations seemed to indicate possibilities of eliminating a conventional coat of finish. Have you made any experiments as to comparisons of coats on Micro-Sealed surfaces and conventional surfaces?

Mr. Elmendorf: No experiments have been made beyond those in which we found that Micro-Sealing can be used in place of a first coat of varnish or lacquer in the case of clear finishes.

Donald Lubeck (Hammond Organ Co.): Is it possible that the surfaces are made too fine for furniture finishing. I have the impression that the coarsest grit that will not leave scratches in subsequent finishing operations is superior to a polished surface. This would be immediately apparent when using a N.G.R. stain.

Mr. Elmendorf: I am not aware of any objections to the smoothness obtained when the wood surface is polish-sanded prior to finishing rather then merely sanded with 4/0 paper.

A COMPARISON OF METHODS OF Evaluating Exterior Natural Finishes[1,2]

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Panels of dark red Philippine mahogany were finished with 18 proprietary finishes. After exposure in a weatherometer for 865 hours, relative durability was determined by visual inspection. Measurements of weight change, gloss, hardness, surface roughness, wetting angle of a water droplet, and tri-stimulus color difference made during weathering were then analyzed graphically to determine whether any of the quantitative techniques would establish durability classes in agreement with the visual classifications.

UP TO THE PRESENT TIME, the service life of finishing materials has been determined by visual inspections. Although measurements have been made in an isolated manner of such properties as tensile strength, elongation, hardness, adhesion, permeability, water absorption, swelling, solubility, gloss, and spectrophotometric absorption, the final basis for the evaluation of durability depends upon a visual analysis.

Knowledge of the properties given above affords an understanding of the process of finish degradation, but has, as yet, served little use in determining the durability of natural finishes. To improve the visual methods of obtaining durability ratings, a number of methods have been proposed that give number ratings to the various qualities and defects observed during the exposure. An over-all weighted average of these factors is then computed. However, no such system has the required reliability to gain general acceptance. In addition to their qualitative and subjective nature, visual analysis techniques currently employed are variable, subject to human frailty, and do not allow for a realistic statistical analysis.

It would be extremely helpful if quantitative testing techniques were available that would provide measurable data indicating the relative durability of natural exterior finishes that would agree with a visual durability rating after the same exposure. Due to the length of time required to conduct exterior exposure tests and the desire for a rapid exposure technique, it seemed advisable to begin a study of quantitative testing techniques applicable to natural finishes after artificial exposures. If a satisfactory quantitative technique could be obtained that would yield relative durability ratings in close agreement with a visual du-

[1] A 1958 Wood Award entry, submitted while the author was in attendance at the New York State College of Forestry at Syracuse.

[2] Presented at the Wood Industries Conference (Joint meeting of the Wood Industries Division, ASME, with FPRS Eastern Canadian and Northeast Sections), held March 30-April 1, 1958, in Syracuse, New York.

The Author: John Burger was a graduate student and fellow in forest utilization at Syracuse until this summer, when he joined DuPont.

Test panels were examined at intervals during accelerated weathering in the weatherometer.

ability rating after artificial weathering, perhaps, in time, and with such a technique, artificial exposure methods could be developed that would approximate the normal exterior weathering of natural finishes with sufficient reliability.

Although weatherometer exposures may not be accepted by some as a sound basis for evaluating the durability of finishes, others justify their use in order to help reduce the time involved in outdoor exposures and with the hope that in the future, a high correlation would be found between weatherometer and exterior exposures. Thus, it was for these reasons that weatherometer exposures were employed in an attempt to correlate visual durability analyses with quantitative testing techniques.

Before explaining more fully the experimental techniques used, it may be advisable to define what is meant by a natural exterior finish. The general thought is that a natural finish is a clear material used to finish the exteriors of homes. Others have observed, however, that the durability of natural finishes is improved when a small amount of pigment is incorporated in the finish or if a clear finish is applied over a prior stain. For this work, the finishing systems were subdivided into 1) stains, 2) clears, and 3) stain and clear combinations. This system was used instead of the more basic system used by the U. S. Forest Products Laboratory because of the lack of information on the specific formulations of the various proprietary products tested.

Although a quantitative analysis would produce the desired information, it is laborious, costly, and beyond our needs at this time. In general, manufacturing policies forbid the release of such specific information as to the type of resins and oils used in their products. Thus, a much more simple, and in reality less valuable, classification system was resorted to where information could be obtained by visual observation only. For reference, the Forest Products Laboratory separates natural exterior finishes into 1) varnish finishes, 2) oil finishes, 3) wood sealer finishes, and 4) water-repellent preservative (non-drying oil) finishes with only the first class being of the film-forming type. [3]

Purpose of the Investigation

The purpose of this study was to investigate six quantitative testing techniques in order to obtain a test method that would yield measurable data (which can be utilized to obtain the relative durability of 18 proprietary exterior natural finishes) that will agree with a visual durability rating after exposure in a weatherometer. A series of small panels of dark red Philippine mahogany were finished with 18 proprietary finishes according to the manufacturers' directions. After conditioning, these panels were exposed in a weatherometer for 865 hours or approximately one month. At intervals of approximately 24 hours, measurements were made of such factors as gloss, hardness, weight change, surface roughness, tri-stimulus color difference, and the wetting angle of a water droplet. The data were expressed in both absolute units and as percentages of the original values.

At the completion of the weatherometer exposures, visual analyses of these 18 finishes were made, and the finishes were separated into four classifications according to their durability. The measurable data were then plotted against the time of exposure. An analysis of these graphs was then made to determine if any of the quantitative techniques used were capable of segregating these 18 finishes into four classes of durability that would agree with the visual durability classifications.

An analysis of these data indicated the tri-stimulus color difference method to be the only suitable method for this purpose. All the other techniques investigated were unable to segregate the finishes into durability classes that would agree with the classifications based on a visual analysis. Thus, the subject of this paper will be limited to the tri-stimulus color difference technique, although the results of the other five methods are given in the conclusions.

Experimental Procedure

Panel Preparation and Exposure: To have a check on the validity of the visual durability ratings, it was decided to repeat the weatherometer exposures or runs two or more times. For each run, a set of 54 panels of dark red Philippine mahogany, *Shorea negrosensis* (red Lauan), and *Shorea polysperma* Tangile), was prepared from nominal 3/8 by 8 by 48 to 60 inch flat grain number one common and better, sound wormy grade, tongue and grooved paneling. It was necessary to

Table 1.—CLASSIFICATION OF MATERIALS TESTED

Type	Composition oils	Composition resins
	Stains	
S-1	Modified drying oil	Alkyd
S-2	Linseed oil and wax	
S-3	Modified drying oil	Alkyd
S-4	Polymerized linseed, tung, soya, and sardine oil	Alkyd
S-5	Unknown	Unknown
S-6	Modified drying oil	Alkyd
S-7	Modified drying oil	Alkyd
S-8	Modified drying oil	Alkyd
S-9	Polymerized linseed and tung oils	Pentaerythritol ester
	Clears	
C-1	Modified drying oil	Unknown
C-2	Linseed oil	Epoxy
C-3	Linseed and tung oils	
C-4	Unknown	Unknown
	Stain and Clear Combinations	
SC-1	Safflower oil	
SC-2	Safflower oil	
SC-3	Special linseed oil	Alkyd
SC-4	Unknown	Unknown
	Paint	
P-1	Linseed oil with white lead and titanium pigments	

[3] Laughnan, Don L., 1954. Natural wood finishes for exteriors of houses. Preprint 547, Forest Products Research Society, Madison, Wis.

use both of the above species since the commercial practice is to distinguish only between the light and dark red Philippine mahogany. Further identification as to the exact species of the dark red panels would be of no commercial benefit.

A record was kept of the position of the test panels in the original boards. The test panels were then conditioned to 12 per cent equilibrium moisture content (EMC) at 75° F. and 66 per cent relative humidity until the panels developed a constant weight.

The large number of finishes tested and the limited space available in the weatherometer prohibited the use of sufficient individual replications to obtain comparisons by visual or statistical methods. However, by a combination of the use of a control finish and the matching of wood specimens, fair visual comparisons were obtained from the 54 test specimens without resorting to a large number of replications. One test panel from each of the original boards was chosen by the use of a random number table. The control finish, designated S–8, was then applied to these test panels. The remaining test panels were then randomly assigned to the balance of the finishes being tested. In all, 18 finishes were exposed during the first, and 17 during the second weatherometer run. Thus, in general there were three test panels for each finish exposed.

Each of the test finishes was then applied to the bark side of their respective panels by brushing along the grain, parallel to the long axis of the panels. Because of the widely differing types of finishes and the varying finishing systems investigated, it was not possible to apply each of the 18 commercial finishes at a constant film thickness. To do so would have jeopardized some of these proprietary products by not conforming to the manufacturers' directions that were necessary for the build required by each product. The end result would not have led to practical finishes. However, an attempt was made to insure equal film thicknesses for the panels coated with each specific finish. This was accomplished by applying constant weights of each specific material according to the manufacturers' instructions regarding spreading rates and number of coats.

After each coat was applied, the panels were dried at 75° F. and 66 per cent relative humidity (12 per cent EMC) for a minimum of 24 hours or according to the manufacturers' directions. Following the drying period, after the final finishing coat, the backs and edges of the panels were sealed with a 12½ gallon oil length tung oil phenolic aluminum sealer according to ASTM Standard D–154. This sealer consists of one gallon of type B varnish, plus two pounds of type B aluminum paste. The panels were then conditioned at 75° F. and 66 per cent relative humidity until a constant weight was obtained.

The panels were then assigned positions in the weatherometer by means of a random number table. At the end of each 24-hour cycle, the panels were reversed top for bottom in their respective positions. ASTM tentative D–822 was followed in the operation of an Atlas X–W Sunshine Arc weatherometer. This specification states that an ambient temparture of 145° ± 5° F. shall be maintained, as measured on a black panel thermometer, with an exposure cycle of 102 minutes of light and 18 minutes of light and water spray. Ordinary city water was used for the water spray because of its soft, mineral-free nature. The exposure was for 865 hours of approximately one month as recommended by the U. S. Forest Products Laboratory. At the end of each exposure period, a visual durability rating was obtained.

Basic Finishing Tests: To obtain basic information regarding the physical characteristics for each of the products tested, determinations were made of viscosity, density, and per cent solids content. The viscosity was determined as the time in seconds required for a constant volume of material to flow through a number four Ford cup under constant 75° F., 66 per cent relative humidity conditions. The weight of 20 cubic centimeters of each material under the above conditions determined the density of the various products. Solids content was obtained according to ASTM Standard D–154. Briefly, this method consists of heating a sample of the material to 105° ± 2° C. until a constant weight is obtained. The final weight of the sample divided by the orginal weight of the sample gives the percentage of solids for each product. The absolute data for each of these tests were listed in numerical order for analysis. It was hoped that such simple determinations would provide an indication of the relative durability of the various test finishes.

Color: By means of photoelectri tri-stimulus data, quantitative expressions can be obtained that correspond to the perceived amounts of surface color changes. In this investigation color differences were obtained by using a Photovolt model 610, 45°, -0 reflectometer with a green, an amber and a blue filter respectively for each measurement. Each filter broke up the incident light into bands of light with a certain wide range of wave lengths The amount reflected from the test surface with each filter was then compared with the respective reflection from a magnesium oxide surface. The changes in color developed by the panels, initially and after each 72-hour period of exposure during the second weatherometer run, were then calculated from the three reflectance readings by means of the equations given below. The apparent reflectance (G,A,B) for illumination at 45° and veiwing at 0° (from a perpendicular to the surface) is compared to a magnesium oxide standard. The data obtained with each of the three filters serves as a basis for future calculations according to the following formulas:

$$L = 10\sqrt{G}$$

$$a = \frac{70\sqrt{G}\,(A-G)}{A+B+2G}$$

$$b = \frac{28\sqrt{G}\,(G-B)}{A+B+2G}$$

An equation for color differences, ΔE, utilizes the apparent reflectance difference (ΔL) and chromaticity differences ($\Delta a, \Delta b$), which are

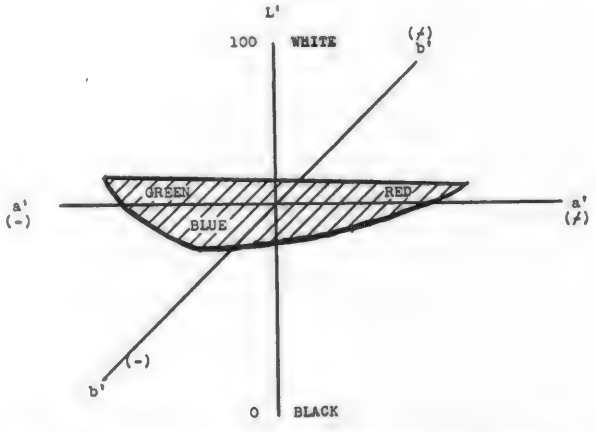

Fig. 1.—Diagram of a given plane of the (a', b', L')-surface-color solid.[4]

eighted and then combined to obtain measure of the resultant (ΔE) expressed in National Bureau of Standds (NBS) units of color differences. hese NBS units were designed so at a difference larger than one unit of visual significance, and the mber of units will be in agreement ith perceived amounts of color difrence. Color difference, ΔE, is the sultant vector of three component fferences: light-index difference ΔL) and chromaticity differences $\Delta a, \Delta b$). This vector notation indites that $\Delta L, \Delta a, \Delta b$ are magnitudes f difference reacting in the direction of L', a' and b', which represents a three-dimensional color solid [4] where distance is a close measure of the perceptibility of corresponding surface-color differences (Fig. 1). The magnitude of the resultant (ΔE) of the $\Delta L, \Delta a$, and Δb vectors, which is defined as the color difference, is a scalar quantity obtained from the following equation:

$$\Delta E = \sqrt{(\Delta L)^2 \ (\Delta a)^2 \ (\Delta b)^2}$$

where $\Delta L = L_1 - L_0$

$\Delta a = a_1 - a_0$

$\Delta b = b_1 - b_0$

The factors L_0, a_0, and b_0 in the above equations are the initial apparent reflectance, and the chromaticities respectively. ΔE will provide no indication of the character of the differences, however, since it does not indicate the relative quantity and direction of hue, saturation, and lightness differences.

A white enamel working standard that produces 83 per cent reflection with the green filter (G), 65 per cent with the amber (A) and 33 per cent with the blue filter (B) was used to standardize the instrument before and after each determination in an effort to eliminate any instrumental drift. As the panels lighten in color, the values with each of the filters will approach the above standards. When darkening occurs, the opposite effect will develop. For each determination, the incident light from the reflectometer was kept parallel to the direction of the grain of the wood to decrease the possibility of irreproducible readings. When conducting measurements for this and the other techniques investigated, the same area of the panel was used for each determination throughout the course of the weatherometer exposures.

After computing average values of L, a, and b for each panel, the color difference ΔE for each of the finishes being tested was obtained. These values, expressed in absolute units and as percentages of the original color differences, were plotted against the time of exposure for the second weatherometer run and then analyzed.

[4] Hunter, Richard S. 1942. Photoelectric tristimulus coorimetry with three filters. Circular 429, National Bureau of Standards, Wash., D. C.

Discussion of Results

General: The numerical listing of viscosity and per cent solids for each of the finishes indicated that there was little, if any, correlation with the relative durability of the test finishes. In general there seemed to be a correlation between the density of the finish and durability. Those finishes with a density of 0.89 gram per cubic centimeter or larger were better in durability than those below this density figure. With equivalent type finishes, the higher density would indicate higher solids and thus the possibility of thicker films being formed, which would be expected to show better durability than the thinner films. This result occurred for the widely differing types of finishes studied, however, such as penetrating stains, clears, film formers, and non film formers. Thus the widely differing film thicknesses for these higher density materials were not the only factor involved in producing durable finishes. Those finishes of the stain and stain-and-clear combinations were better in durability than the clear finishes tested. The matching and use of control finishes indicated that there was very little variation between panels from the same or different boards.

Four visual classifications were used to rate the finishes for durability. The "good" classification includes those finishes which develop few surface defects and little loss of finish after 865 hours in the weatherometer. The "fair" classification includes those finishes which develop small and numerous areas of loss of finish and color. The "poor" classification includes those which develop a pronounced loss of finish but whose surface has a uniform color and an acceptable appearance. The "failure" classification has a complete loss of finish, with either a burned or a bleached surface, depending upon the extent of exposure after the complete loss of finish. Tables 2 and 3 list the finishes in order of decreasing durability in each of these four classifications. When these tables are used, it must be remembered that these visual durability ratings were obtained after artificial weathering in a weatherometer. However, these ratings agree with those of the Timber Engineering Company for outdoor exposure weathering for four of the finishes tested (materials foot noted in Tables 2 and 3).

In comparing Table 2 with Table 3, it may be noticed that the appearance and the over-all groupings were approximately the same, but that the individual finishes may have shifted their positions within a group. The S–8 finish has moved from the poor to the fair class. This individual shifting may be the result of using a qualitative visual judgment instead of a quantitative measurement technique, or due to experimental error such as a longer conditioning period before

Table 2.—VISUAL DURABILITY RATING FOR 18 TEST FINISHES ON DARK RED PHILIPPINE MAHOGANY AFTER 865 HOURS AT THE END OF THE FIRST WEATHEROMETER RUN

Good

[1]S-1: Little loss of film—even color a few small white streaks started.
P-1: Little loss of film—two large yellow areas.
S-2: Little loss of film—even color—a few small white streaks started.
S-3: Little loss of film—fairly even color—small white streaks started.

Fair

SC-1: Some film loss—fairly even color—small white streaks and spots.
SC-2: Some film loss—fairly even color—small white streaks and spots.
[1]SC-3: Some film loss—streaks of color—fairly large white streaks.

Poor

[1]S-4: Most of film lost—fairly even color—large streaks and areas of white.
[1]S-5: Most of film lost—streaks of color—large white streaks.
S-8: Some film loss—two large dark green areas—large number of small white streaks.
S-7: Some film loss—two large dark pink areas—large number of small white streaks.
S-8: Most of film lost—spotty color—large number of white streaks and spots.
S-9: Most of film lost—spotty color—large number of white spots.

Failure

C-1: Nearly all film lost—few streaks of color—large streaks and areas of white.
C-2: All of film lost—even bleached color—film badly crazed before failure.
SC-4: All of film lost—even white—gray color.
C-3: All of film lost—even white color.
C-4: All of film lost—fairly even white color.

[1]Materials tested by Timber Engineering Company.

Table 3.—VISUAL DURABILITY RATING FOR 17 TEST FINISHES ON DARK RED PHILIPPINE MAHOGANY AFTER 865 HOURS AT THE END OF THE SECOND WEATHEROMETER RUN

Good

S-3: Little loss of film—even color—small white streaks started.
S-2: Little loss of film—even color a few small white streaks started.
P-1: Little loss of film—large yellow areas.
[1]S-1: Little loss of film—fairly even color—a few small white streaks started.

Fair

S-8: Some of film lost—spotty color a number of white streaks and spots.
[1]SC-3: Some film loss—streaks of color—fairly large white streaks.
SC-2: Some film loss—fairly even color—small white streaks and spots.
SC-1: Some film loss—fairly even color—small white streaks and spots.

Poor

[1]S-4: Most of film lost—fairly even color—large streaks and areas of white.
[1]S-5: Most of film lost—streaks of color—large white streaks.
S-7: Some of film lost—two large dark pink areas—large number of small white streaks.
S-9: Most of film lost—spotty color—large number of white spots.

Failure

C-1: Nearly all of film lost—few streaks of color large streaks and areas of white.
C-2: All of film lost—even bleached color—film badly crazed before failure.
SC-4: All of film lost—even white—gray color.
C-3: All of film lost—even white color.
C-4: All of film lost—fairly even white color.

[1]Materials tested by Timber Engineering Company.

being exposed in the weatherometer. The panels for the second run were conditioned for over a week after the final finishing coat had been applied instead of the intended 48 hours. This delay may have caused both the S–1 and S–8 finishes to develop a whitish cast that was not present in the first weatherometer run. Again, this increased conditioning may have been the factor that produced a more severe state of yellowing for the white paint, P–1, during the second run. Little, if any, variability either within or between samples from the same or different boards was found by a visual analysis at the end of the weatherometer runs.

The results seem to indicate that, with such a large number of finishes and with only three replications, the variance within each finish is of such a magnitude as to confound the variance between the various finishes for each of the six techniques analyzed. Although some of the graphical representations were able to separate the "good" from the "failure" group finishes, there was usually at least one finish that was not separated. The finishes in the "fair" and "poor" classifications were seldom separated to any extent. There is no statistical technique that will tell which finish is better than any other. All statistics can attain is that the finishes are either the same or differ in a particular quality. In the future, therefore, it would be more reasonable to reduce the number of finishes tested and to increase the replications to obtain a clearer analysis.

The graphical presentation of the data for each of the six testing techniques investigated is not given, because of the complex and confusing picture that was produced. Only in the analysis of color was there a sufficient spread between the various finishes to be clearly observable. However, this situation existed for the color technique only after a period of 500 hours of weathering.

One weakness of this type of testing is that the nature of the systems tested was unknown except to the manufacturer, and thus no basis of information was developed that could help provide improved finishes.

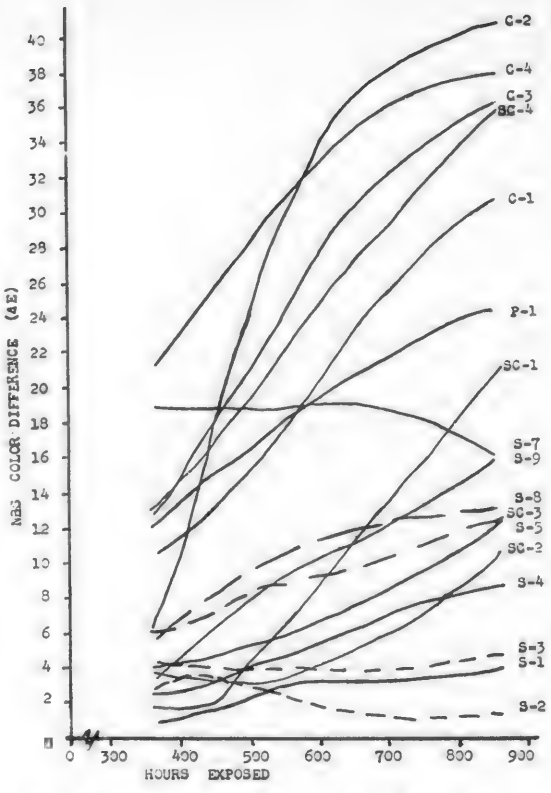

Fig. 2.—NBS color differences for each finish during the second weatherometer run.

Color: Color differences, when plotted as percentages of the original color differences, increased at a rapid rate with the exception of the S–2 finish, which remained fairly constant throughout the second weatherometer run. This method was able to separate only two of the "good" class finishes, while the other finishes were not presented in any systemic order. Color differences in absolute, National Bureau of Standards color difference units were able to separate all the finishes into three groups. The first group consisted of those finishes of the "failure" class (as determined by a visual analysis) whose color difference increased rapidly as the weathering progressed. The second group was composed of those finishes of the "good" class, whose color difference remained constant or increased only slightly. The third group consisted of both the "fair" and the "poor" class finishes, whose color difference increased at a moderate rate during the weatherometer run. The white paint, P–1, was also included in this third group of finishes with an intermediate range of color differences.

The third group of finishes, which was separated by means of absolute color difference, can be further subdivided into two other groups corresponding to the "fair" and the "poor" finishes by means of their gloss ratings (either as percentages or in abso-

Table 4.—AVERAGE PER CENT OF ORIGINAL COLOR DIFFERENCE VALUES FOR EACH FINISH DURING THE SECOND WEATHEROMETER RUN[1]

Hours exposed	0	59.7	109.7	214.0	278.0	366.0	432.0	517.0	569.5	650.5	863.0
Finish											
SC-2	0.00	100.00	151.5	107.2	136.6	91.0	114.7	55.5	118.4	123.9	263.
C-3	.00	100.00	64.4	48.5	97.5	139.1	183.9	238.9	305.4	322.2	398.
SC-4	.00	100.00	91.6	165.0	329.4	412.0	529.8	638.8	751.8	872.8	1166.
S-5	.00	100.00	76.6	109.9	107.4	111.0	145.5	140.2	189.8	203.6	340.
S-8	.00	100.00	85.2	72.9	151.0	149.6	209.6	261.6	313.2	328.8	371.
C-1	.00	100.00	97.9	97.9	120.6	114.0	123.2	169.7	194.3	255.7	332.
SC-1	.00	100.00	63.5	207.6	207.6	63.5	34.8	136.0	224.9	292.1	604
S-2	.00	100.00	48.3	682.1	125.4	74.6	117.5	74.6	77.6	40.8	42
C-2	.00	100.00	87.4	98.2	67.8	66.3	165.6	296.8	351.7	415.5	463.
C-4	.00	100.00	60.0	153.9	225.9	294.8	348.2	401.1	439.4	488.3	533.
S-9	.00	100.00	56.9	35.4	28.1	56.6	93.1	124.7	176.3	182.3	269
S-1	.00	100.00	101.1	29.8	29.8	24.3	40.9	77.9	101.9	75.7	112
S-3	.00	100.00	88.4	171.3	171.3	247.0	247.0	172.6	367.7	228.0	293
S-7	.00	100.00	205.1	552.3	652.8	886.0	886.0	854.7	907.0	907.9	747.
SC-3	.00	100.00	100.0	103.7	103.5	131.8	105.9	223.8	174.7	197.6	256
S-4	.00	100.00	177.5	62.4	87.1	93.4	45.0	204.4	215.1	237.3	321
P-1	.00	100.00	76.4	152.0	199.8	273.6	338.6	375.2	424.1	466.8	557

[1]Averages of three test panels for each finish except the S-8 finish, which is an average of 6 test panels.

ite units) or by their percentage eight difference ratings during the st 400 hours of the weathering expo- ire. All the other techniques inves- gated to date were able to separate is third group of finishes into the 'air" and the "poor" class finishes vith the exception of the S–8 finish), it at only certain specific times dur- g the course of the weatherometer n. Thus, by a combination of the ove methods, natural finishes may be rouped into four classes of durability hat will agree with the durability clas- ifications based on a visual analysis of t e weatherometer exposures. These t chniques may even be able to rate finishes according to durability within, as well as between, the durability classes.

A limitation of the reflectometer in determining color differences was the difficulty of designing filters to correspond to the ICI distribution curves, since color filters cannot be found that duplicate perfectly the desired tristimulus functions. The result is that true a'–b' chromaticity coordinates can be obtained only for near whites. The further a color is from the white point, the greater is the error involved. To overcome these difficulties, the meter should only be operated as a difference meter to compare colors close together in the color solid. In the case at hand, the colors had some degree of spread generally from dark brown to dull red.

Also, the filters used with reflectometers pass broad wave-length bands and, in general, will not give meaningful absolute color curves. Since the errors of measurement were probably of a magnitude that would not be too serious for comparative color difference determinations, however, no attempt was made to correct the readings for failure of the source-filter-photocell combinations to be spectrally equivalent to the ICI observer.

Conclusions

1. The finishes with a density of 0.89 gram per cubic centimeter or larger were generally better in durability than those below this density figure.

2. Little variability within or between panels from the same or different boards was encountered at the end of either weatherometer run (865 hours).

3. No clear-cut method of obtaining the relative durability of exterior finishes for dark red Philippine mahogany has been found by a graphical analysis of gloss, hardness, and weight change, in absolute values, or as percentages of the original values. Exceptions from the visual ratings were found in each case.

4. Absolute gloss, absolute hardness, and per cent of original hardness were successful in separating the better from the poorer finishes, and may deserve more study. Per cent of original weight difference, absolute weight difference, and per cent of original weight were able to separate only a few of the better from the poorer finishes, but should not be overlooked for future study.

5. A graphical analysis of absolute color differences developed during the second weatherometer run was able to segregate the "good" and the "failure" class finishes in all cases except the white paint, P–1, which is not a natural finish.

6. The remaining finishes not separated on a basis of absolute color differences were segregated into the "fair" and the "poor" class finishes by means of absolute gloss, percentage of original gloss, and percentage of original weight difference ratings during the last half of the 865-hour weatherometer exposures.

7. Techniques such as gloss, hardness, weight change, weight difference, wetting angle, and surface roughness, although unable to segregate natural exterior finishes into any of the four classes of durability, were able to break down those finishes of intermediate durability (as segregated by means of absolute color difference), with the exception of the S–8 finish, into the "fair" and the "poor" class finishes, but only at certain specific times during the weathering periods.

8. Wetting angle and surface roughness measurements, whether expressed as percentages of the original values or in absolute units, provided no clear-cut method of determining the relative durability of natural exterior finishes for dark red Philippine mahogany. Color difference expressed as a percentage of the original color difference also failed to yield a testing technique that would determine the relative durability of exterior finishes.

Table 5.—AVERAGE COLOR DIFFERENCE IN NBS UNITS FOR EACH FINISH DURING THE SECOND WEATHEROMETER RUN[1]

Hours exposed	0	59.7	109.7	214.0	278.0	366.0	432.0	517.0	569.5	650.5	863.0
Finish											
SC-2	0.00	4.02	6.09	4.31	5.49	3.66	4.61	2.23	4.76	4.98	10.59
C-3	.00	9.09	5.85	4.41	8.86	12.64	16.72	21.72	27.76	29.29	36.25
SC-4	.00	3.09	2.83	5.10	10.18	12.73	16.37	19.74	23.23	26.97	36.03
S-5	.00	3.63	2.78	3.99	3.90	4.03	5.28	5.09	6.89	7.39	12.37
S-8	.00	3.65	3.11	2.66	5.51	5.46	7.65	9.55	11.43	12.00	13.57
C-1	.00	9.26	9.07	9.07	11.17	10.56	11.41	15.71	17.99	23.68	30.81
SC-1	.00	3.53	2.24	7.33	7.33	2.24	1.23	4.80	7.94	10.31	21.32
S-2	.00	3.31	1.60	22.58	4.15	2.47	3.89	2.47	2.57	1.35	1.40
C-2	.00	8.75	7.65	8.59	5.93	5.80	14.49	25.97	30.77	36.36	40.57
C-4	.00	7.10	4.26	10.93	16.04	20.93	24.72	28.48	31.20	34.67	37.91
S-9	.00	5.94	3.38	2.10	1.67	3.36	5.53	7.41	10.47	10.83	16.03
S-1	.00	3.62	3.66	1.08	1.08	0.88	1.48	2.82	3.69	2.74	4.07
S-3	.00	1.64	1.45	2.81	2.81	4.05	4.05	2.83	6.03	3.74	4.81
S-7	.00	2.14	4.39	11.82	13.97	18.96	18.96	18.29	19.41	19.43	15.99
SC-3	.00	4.91	4.91	5.09	5.08	6.47	5.20	10.99	8.58	9.70	12.60
S-4	.00	2.71	4.81	1.69	2.36	2.53	1.22	5.54	5.83	6.43	8.72
P-1	.00	4.40	3.36	6.69	8.79	12.04	14.90	16.51	18.66	20.54	24.54

[1]Averages of three test panels for each finish except the S-8 finish, which is an average of 6 test panels.

THE FUNDAMENTALS OF
Water Vapor Sorption by Wood[1,2]

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Experimental sorption data for 16 species, of both domestic and tropical origin, and acetylated white spruce were treated by means of a theoretical equation. The descriptive results obtained were found to be in basic agreement with the results of previous workers. In view of the apparent applicability of the theoretical solid-solution model, fundamental conclusions are drawn concerning the sorption characteristics of wood.

ATTEMPTS TO MEASURE PHYSICALLY the distribution of sorbed water in the two modes by which it is held within the cell wall have been thwarted by experimental difficulties. As a result, the mechanism devised to explain the sorption characteristics of cellulosic materials is based essentially on circumstantial evidence. It has been suggested that a theoretical model can be applied to sorption isotherms that will enable the evaluation of the sorption phenomenon for wood. Such a technique has obvious limitations, but in view of the insight that may be gained, and possible indications of areas for further investigation, the treatment has considerable merit.

Of the few theoretical sorption models published in the literature, that derived by Hailwood and Horrobin (2)[3] has been well received by polymer chemists. Not only does it provide a measure of the water bound directly to the polymer and that condensed in the void volume of the polymer, but it also provides a measure of the degree of orientation within the polymer structure. The model is based upon the assumption that sorbed water exists in two states, simple solution, and combined to form a hydrate with a definite unit of the polymer fiber. Furthermore, it is assumed that the free dissolved water, unhydrated polymer, and hydrated polymer form an ideal solid solution.

The derivation, as carried out by Hailwood and Horrobin, provides the means for equating the activities (effective concentrations) of the water vapor, the free dissolved water in the solid phase, and the hydrate water to their mole fractions (molecular concentrations) on the assumption of an ideal solid solution. The equilibrium between the fractional humidity (relative humidity) h and free dissolved water is measured by α. The equilibrium constants of the hydrates (monohydrate, dihydrate, and so forth) are represented by β. Equilibrium between (a) the dissolved water and external vapor pressure, and (b) between the dissolved water and hydrate water, is assured by assuming that the water molecules in the solid phase are mobile. Hailwood and Horrobin state that the postulate of a monohydrate is adequate to fit the experimental data for polymer systems; therefore, the isotherm equation is

$$\frac{Mr}{1800} = \frac{\alpha h}{1 - \alpha h} + \frac{\alpha\beta h}{1 + \alpha\beta h} \quad \text{---- 1)}$$

where M equals the molecular weight of the polymer substance necessary to associate with one molecular weight of water, and r equals the moisture content at a given relative humidity h.

Equation 1 can be algebraically transformed to

$$A + Bh - Ch^2 = \frac{h}{r} \quad \text{---------- 2)}$$

for convenience in fitting to the experimental data. In the form of equation 2, equation 1 is

$$\frac{M}{1800\,\alpha(\beta + 1)} + \frac{\alpha M(\beta - 1)}{1800\,\alpha(\beta + 1)}\,h - \frac{\alpha^2\beta M}{1800\,\alpha(\beta + 1)}\,h^2 = \frac{h}{r}$$

Thus,

$$A = \frac{M}{1800\,\alpha(\beta + 1)}, \quad B = \frac{\alpha M(\beta - 1)}{1800\,\alpha(\beta + 1)}, \quad C = \frac{\alpha^2\beta M}{1800\,\alpha(\beta + 1)}$$

The common relationship between A, B, and C is

$$\frac{M}{1800} = A\alpha(\beta + 1) \quad \text{---------- 3}$$

$$\frac{M}{1800} = \frac{B(\beta + 1)}{(\beta - 1)} \quad \text{---------- 4}$$

$$\frac{M}{1800} = \frac{C(\beta + 1)}{\alpha\beta} \quad \text{---------- 5}$$

By equating equations 3 and 4 and solving for α,

$$\alpha = B/A(\beta - 1) \quad \text{---------- 6)}$$

Equating equations 4 and 5, and letting $\alpha = B/A(\beta - 1)$,

$$\beta = \frac{\left(2 + \frac{B^2}{AC}\right) \pm \sqrt{\left(2 + \frac{B^2}{AC}\right)^2 - 4}}{2} \quad \text{---------- 7}$$

From equation 7, β can be computed in terms of the fitted constants, A, B, and C. Reverting to equations 6 and 3, α and M can be calculated.

If all glucose anhydrides are operative in sorption, the calculated value for M would be 162. Since this is seldom the case, the value for M will be proportionally larger. The percentage of glucose anhydrides that are inoperative in sorption (per cent inaccessibility) may be calculated from the formula

$$\frac{100(M - 162)}{M} \quad \text{---------- 8)}$$

The two terms to the right of equation 1 divide the total water sorbed into two forms, free dissolved water in the solid state (capillary-condensed water) and hydrate water (surface-bound water). The surface-bound water is

$$r_H = \left(\frac{\alpha\beta h}{1 + \alpha\beta h}\right)\frac{1800}{M} \quad \text{---- 9)}$$

and the capillary-condensed water is

$$r_S = \left(\frac{\alpha h}{1 - \alpha h}\right)\frac{1800}{M} \quad \text{----- 10)}$$

[1] First-place winner, 1958 Wood Award Competition.

[2] This research is part of a comprehensive study being conducted at the Yale School of Forestry in cooperation with the Office of Naval Research, U. S. Navy, under Contract Nonr 609(13), Project NR 330-001, Properties of Tropical Woods.

[3] Numbers in parentheses refer to the Literature Cited at the end of this paper.

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Equation 9 is similar to that derived by Langmuir (5) for solids that sorb a unimolecular layer of gas on their surfaces. Assuming that a finite number of sites exists on the surface of a solid to which gas molecules can be attached, Langmuir derived a parabolic equation that has been found to describe accurately the experimental data for unimolecular systems. The Langmuir equation is

$$\Theta' = \frac{a\mu}{\gamma + a\mu}$$

where Θ' equals the ratio of the number of occupied sites to the total number of sites, μ equals the number of gas molecules that strike the surface, a equals the ratio of the number that condense on the surface to the number that strike the surface, and γ equals the rate at which molecules evaporate from the saturated surface. The number of collisions between the gas molecules and the plane surface is a function of gas pressure, p, and Θ' is proportional to the weight (x) of gas sorbed per unit weight (m) of solid. By equating a/γ to σ, Langmuir's equation may be written as

$$\frac{x}{m} = \frac{\sigma p}{1 + \sigma p} .$$

The equation describes an isotherm that rises steeply in the ranges of low vapor pressure and, with increasing gas pressure, approaches an asymptote of surface saturation. Presumably, the process by which water molecules are associated directly to the internal surfaces of wood substance is described by the Langmuir equation.

One limitation of the Hailwood-Horrobin equation that cannot be overlooked is its failure to account explicitly for hysteresis in sorption. Since the equation provides an insight into the sorption behavior of the cellulose gel, a comparison of the adsorption and desorption isotherms, in terms of their physical constants, may permit a qualified description of the entire sorption phenomenon. In this study, the theoretical equation is applied to the isothermal data of 16 species, of both domestic and tropical origin, tested in adsorption and desorption. In addition, results obtained with acetylated white spruce are similarly analyzed in order to evaluate the influence of active surface hydroxyls on the sorption isotherms and hysteresis. Deactivation of the cellulose hydroxyls, which are presumably the basic cause of sorption hysteresis, is expected to alter significantly the nature and magnitude of hysteresis. Since experimental results of adsorption-desorption tests on acetylated material have not been reported in the literature, the specific influence of reduced surface hygroscopicity on hysteresis cannot be evaluated from past work.

Experimental

The high-vacuum apparatus and basic experimental procedure used in this study have been described in a previous paper (9). All sorption tests were carried out under vacuum at a temperature of 90 ± 0.1° F. The specimens were weighed directly in the system by measuring the elongation of calibrated quartz coils to 0.1 mm. with a cathetometer. Vapor pressures, provided by constantly agitated, saturated salt solutions, were determined by measuring with a cathetometer the differential heights of mercury minisci in a manometer.

The thickness of cross-sectional wafers was held constant at 2.0 ± 0.15 mm., and the width and length were varied to obtain a dry weight of approximately 1000 mg. The load-elongation characteristics of the coils and the accuracy of the cathetometer permitted weighing samples of dry weight in excess of 1000 mg. to one part in 1000 or 0.1 per cent moisture content.

Deactivation of surface hydroxyls by esterification with acetic anhydride was carried out in a glass reaction tube fitted with a precision ground joint and stopcock. Prior to acetylation, the samples of white spruces were dried to constant weight by continuous evacuation of the high-vacuum system through a liquid nitrogen trap. The vapor-phase acetylation reaction, employing a solution of equal parts by volume of pyridine and acetic anhydride, was initiated in the evacuated reaction tube and allowed to proceed for one month. During this period, the reaction vessel was immersed in the constant-temperature bath controlled at a temperature of 90° F. At the end of the reaction period, excess reagents sorbed by the material were removed by prolonged evacuation of the vessel. As a final step, the acetylated material was oven dried to constant weight and then taken through a single desorption-adsorption cycle.

With the exception of untreated spruce, all specimens were initiated to test in desorption from saturation. Air-dry material was saturated between damp cloths. Material in the original green condition was machined and

Table 1.—FITTED AND PHYSICAL CONSTANTS OF THE STABLE ISOTHERMS FOR THE 16 SPECIES AND ACETYLATED SPRUCE.

Species	Test	A	B	Cx10^{-3}	α	β	M
Softwoods							
White spruce (*Picea glauca*)	Des.	1.388332	0.103047	0.839524	7.40770	11.01980	222.51
	Ads.	2.208772	0.121251	1.033413	7.49862	8.32071	277.88
Western white pine (*Pinus monticola*)	Des.	2.206043	0.097200	0.832042	7.33801	7.00446	233.24
	Ads.	2.992775	0.111713	0.997693	7.44568	6.01332	281.30
Ponderosa pine (*Pinus ponderosa*)	Des.	2.059377	0.100196	0.846719	7.34253	7.62626	234.79
	Ads.	2.828586	0.116337	1.039751	7.55107	6.44678	286.30
Western hemlock (*Tsuga heterophylla*)	Des.	1.970916	0.085508	0.705184	7.08875	7.12025	204.21
	Ads.	2.041868	0.120161	1.028008	7.57913	8.76455	272.00
Douglas fir (*Pseudo-tsuga Menziesii* (Mirb) Franco)	Des.	2.013061	0.089864	0.768786	7.34611	7.07675	214.99
	Ads.	1.928106	0.135415	1.171182	7.78573	10.02062	297.79
Western redcedar (*Thuja plicata*)	Des.	2.380091	0.084688	0.661147	6.58733	6.40156	208.88
	Ads.	2.530753	0.128949	1.089188	7.37825	7.90582	299.33
Redwood (*Sequoia sempervirens*)	Des.	1.773698	0.098456	0.725338	6.58577	9.42861	219.27
	Ads.	2.266676	0.138354	1.172139	7.54050	9.09473	310.57
Caribbean pine (*Pinus caribaea*)	Des.	2.196303	0.097377	0.840996	7.40105	6.99060	233.80
	Ads.	2.125481	0.148426	1.300226	7.87257	9.87026	327.41
Hardwoods							
Basswood (Tilia americana)	Des.	2.799807	0.088427	0.830834	7.57764	5.16796	235.55
	Ads.	2.324448	0.163748	1.549834	8.30396	9.49438	364.14
Ceiba (*Ceiba pentandra*)	Des.	1.208047	0.125643	1.079257	7.97791	14.03663	260.85
	Ads.	1.825764	0.149555	1.350096	8.23546	10.98282	323.13
Copaia (*Jacaranda copaia*)	Des.	1.811601	0.103415	0.910392	7.75089	8.36495	236.70
	Ads.	2.179336	0.132372	1.155910	7.74477	8.84266	299.03
Angelique (*Dicorynia paraensis*)	Des.	1.981982	0.090793	0.778455	7.38296	7.20472	216.11
	Ads.	2.218972	0.124817	1.070438	7.56000	8.44047	285.06
Mahogany (*Swietenia* sp.)	Des.	2.442295	0.071425	0.546654	6.29751	5.64408	183.93
	Ads.	2.414178	0.122295	1.029852	7.35357	7.88876	284.04
Teak (*Tectona grandis*)	Des.	3.107242	0.076397	0.623023	6.45853	4.80687	209.76
	Ads.	2.935678	0.136298	1.187529	7.50090	7.18967	324.61
Santa Maria (*Calophyllum brasiliense*)	Des.	2.268587	0.070176	0.566554	6.64563	5.65476	180.59
	Ads.	2.309149	0.115651	0.949663	7.18466	7.97385	267.87
Kokerhart (*Licaria cayennensis*)	Des.	2.952778	0.071826	0.554341	6.15859	4.94975	194.75
	Ads.	3.279023	0.131916	1.144982	7.32366	6.49319	323.90
Acetylated white spruce	Des.	10.376555	0.132022	1.465830	7.11928	2.78713	503.59
	Ads.	11.744237	0.196902	2.068375	7.31395	3.29231	663.65

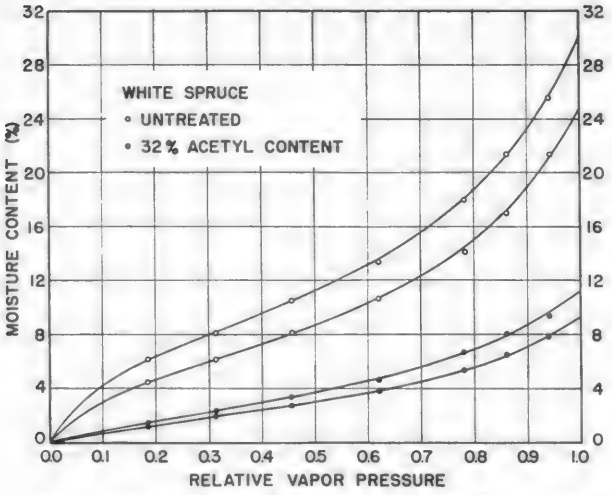

Fig. 1.—Sorption isotherms for previously air-dried white spruce and acetylated spruce at 90° F. The plotted points were obtained experimentally; the isotherms were calculated from the experimental data by means of equation 2.

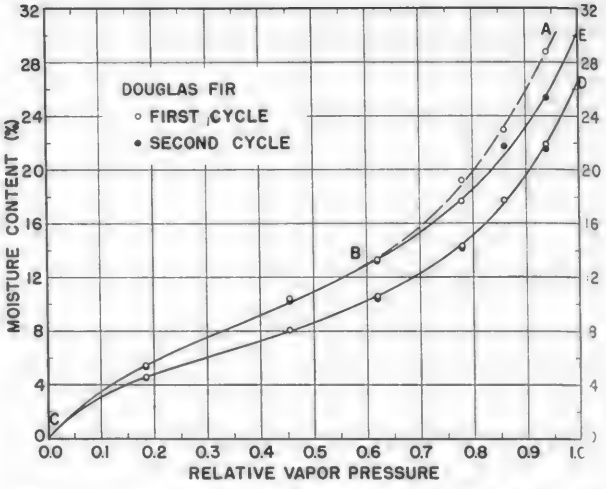

Fig. 2.—Sorption isotherms for Douglas-fir at 90° F., tested in two cycles from the green condition. The significance of the letters on curves is explained in the text.

stored while saturated. As a final step in desorption, the specimens were vacuum dried before readsorption. Specimens tested in initial desorption were saturated in the system between the adsorption and second desorption tests by prolonged exposure to a saturated vapor pressure produced by heating the salt solution to a temperature that caused free condensation in the weighing tubes.

Results

All equilibrium moisture contents were calculated on the basis of vacuum-dry weight taken at a temperature of 90° F. These values were then converted to a parabolic metameter by dividing the relative humidity by the equilibrium moisture content. The transformed values were fitted to equation 2 by the method of least squares from which the fitted constants A, B, and C were obtained and physical constants α, β, and M were calculated. These constants are given in Table 1 for all species tested. Isotherms for the species can be obtained by substituting the fitted constants into equation 2 and dividing the relative humidity by h/r.

The isotherms for seven species are shown in Figs. 1 through 7. These stable isotherms were calculated from all the experimental points plotted by means of equation 2. All the species that had not been previously dried exhibited an initial desorption isotherm that was above subsequent desorption isotherms in the upper reaches of vapor pressure. In all cases, the first and second desorption curves were coincident below 0.50 relative vapor pressure, indicating that the mechanism responsible for the higher initial desorption equilibria is operative only in the range of high relative vapor pressure.

Conventionally, the stable sorption isotherms for wood are extrapolated to a common intersection at vapor saturation. The saturation limit obtained from equation 2 was consistently lower in adsorption, but no deviation was made from the equilibrium trend predicted by the equation. The common intersection point at zero relative vapor pressure is justified physically and is consistent with the equilibrium trend predicted by equation 2.

The relation between relative vapor pressure and the distribution of water into the two forms by which it is held in the cell wall of wood is shown in Fig. 8. The isotherms for surface-bound and capillary-condensed water, calculated from equation 9 and 10 are drawn for both untreated and acetylated white spruce. The isotherm for water bound directly to the surfaces of untreated spruce rises steeply in the range of low vapor pressure, and ap-

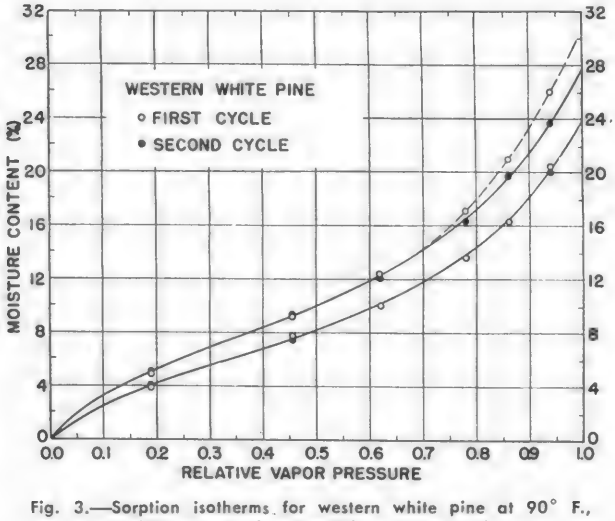

Fig. 3.—Sorption isotherms for western white pine at 90° F., tested in two cycles from the green condition.

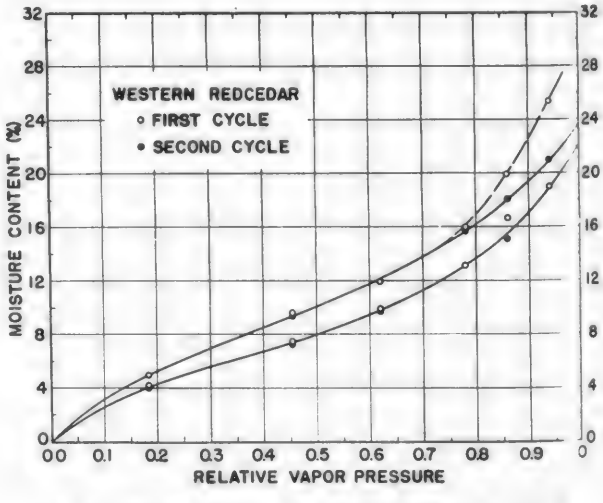

Fig. 4.—Sorption isotherms for western redcedar at 90° F tested from the green condition.

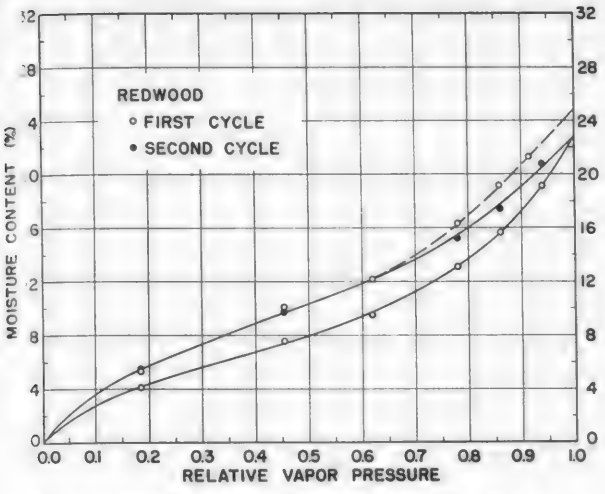

Fig. 5.—Sorption isotherms for redwood at 90° F., tested in two cycles from the green condition.

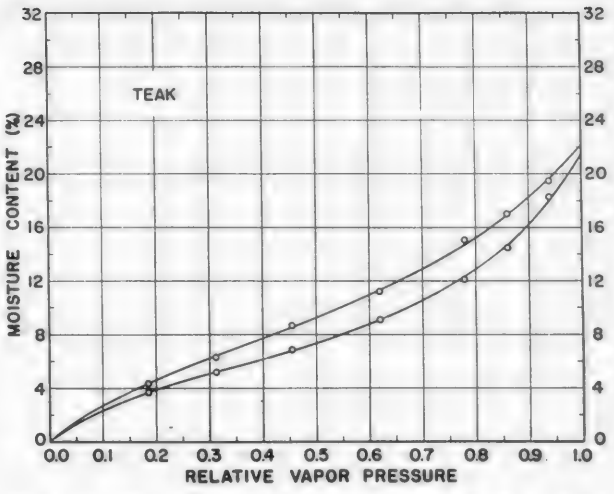

Fig. 6.—Sorption isotherms for previously air-dried teak at 90° F.

proaches an asymptote of surface saturation in the proximity of vapor saturation. This is typical of sorption systems that adsorb a unimolecular layer of gas to the surface of the solid as described by Langmuir. An acetyl content of 32 per cent, corresponding to a substitution number[4] of 1.8, causes a 67 per cent reduction in surface-bound water at saturation during desorption. In the range of low vapor pressures, the reduction is even greater.

The relation between the total water sorbed at saturation for all species and the form in which it is held within the cell wall is shown in Fig. 9 and Table 2. Variation in surface-bound water appears to be virtually independent of the total water sorbed, as indicated by the regression analysis in Table 3. The variation in surface-bound water between species is primarily a function of the availability of the glucose anhydrides, as shown in Fig. 10.

The regression analysis of surface sorption on the percentage of glucose anhydrides inoperative in sorption (per cent inaccessibility) accounts for approximately 80 per cent of the variation in surface sorption between species. The linear relationship between surface saturation and per cent inaccessibility defines a limit of 8.7 per cent moisture content at zero per cent inaccessibility. Therefore, each mole of glucose anhydride in the fully disoriented cell wall associates 0.76 mole of water, which corresponds to a hydrate of $C_6H_{10}O_5 \cdot \frac{3}{4} H_2O$. On the basis of these calculations, the assumption of a monohydrate is not violated.

Capillary condensation, on the other hand, is shown in Fig. 9 and Table 3 to account for approximately 98 per cent of the variation in the total water sorbed at saturation. The contribution of capillary condensation to the hygroscopicity of wood is revealed in Table 4. Esterification of 60 per cent of the hydroxyls produced a 67 per cent reduction in surface sorption and a 62 per cent decline in capillary condensation. However, 76 per cent of the reduction in the total water sorbed is brought about through the bulking of capillaries by the ester. Species with the lowest fiber saturation points (western redcedar, redwood, teak, mahogany, and kaneelhart) are also known to have a high extractive con-

[4] The substitution number is the average number of hydroxyls acetylated per glucose anhydride. In this instance, it is assumed that all hydroxyl esterification is confined to cellulose.

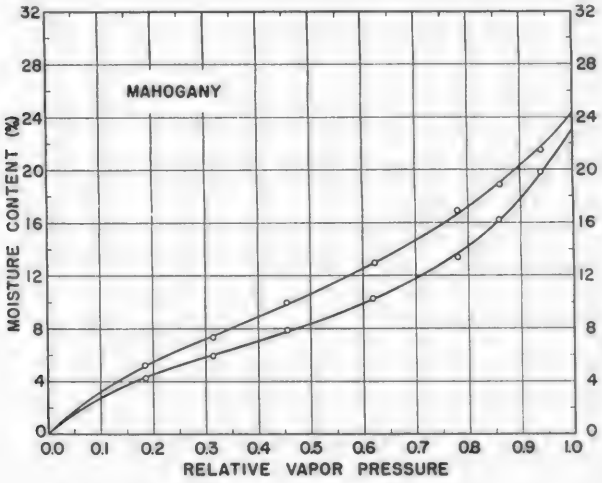

Fig. 7.—Sorption isotherms for previously air-dried mahogany (*Swietenia* sp.) at 90° F.

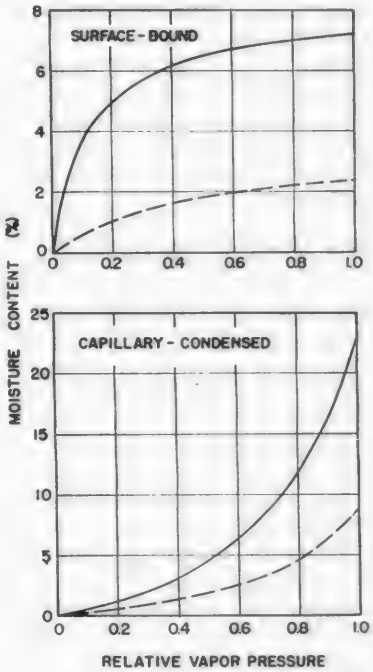

Fig. 8.—Desorption isotherms of surface-bound and capillary-condensed water for white spruce and acetylated spruce (dashed line). The isotherms were calculated by means of equations 9 and 10, and the values of α, β, and M reported in Table 1.

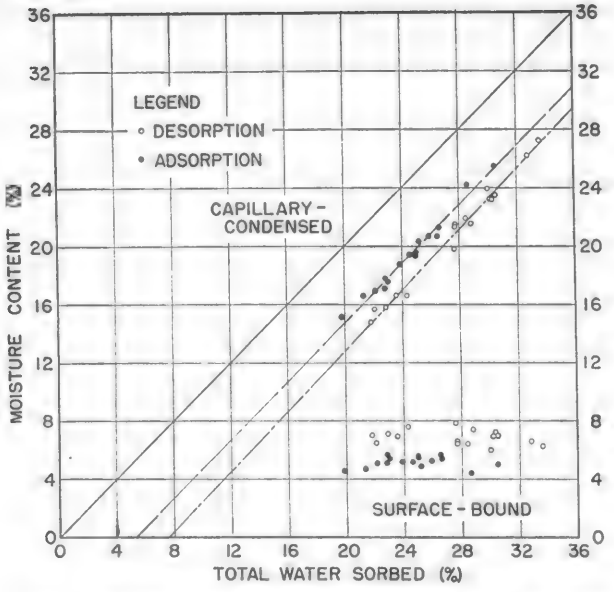

Fig. 9.—Relation between the total water sorbed and distribution of water into the surface-bound and capillary-condensed form. The two dashed lines are the fitted regressions of fiber saturation point on capillary-condensed water in adsorption and desorption.

Table 2.—THE DISTRIBUTION OF SORBED WATER AND THE PER CENT INACCESSIBILITY OF THE FULLY-SWOLLEN CELL WALLS OF 16 SPECIES OF WOOD AND ACETYLATED WHITE SPRUCE

Species	Test	Inaccessibility, per cent	Surface bond, per cent	Capillary condensed, per cent	Total water sorbed, per cent
Softwoods					
White spruce	Des.	27.19	7.2	23.1	30.3
	Ads.	41.70	5.6	19.4	25.0
Western white pine	Des.	30.54	6.5	21.3	27.7
	Ads.	42.41	5.2	18.7	23.9
Ponderosa pine	Des.	31.00	6.5	21.2	27.7
	Ads.	43.41	5.2	19.4	24.6
Western hemlock	Des.	20.67	7.4	21.5	28.8
	Ads.	40.44	5.8	20.7	26.5
Douglas-fir	Des.	24.65	7.0	23.2	30.2
	Ads.	45.60	5.4	21.3	26.6
Western redcedar	Des.	22.44	7.0	16.6	23.6
	Ads.	45.88	5.1	16.9	22.1
Redwood	Des.	26.12	7.1	15.8	22.9
	Ads.	47.84	5.1	17.8	22.8
Caribbean pine	Des.	30.71	6.5	21.9	28.4
	Ads.	50.52	4.9	20.3	25.2
Hardwoods					
Basswood	Des.	31.22	6.1	23.9	30.0
	Ads.	55.51	4.4	24.2	28.6
Ceiba	Des.	37.89	6.3	27.2	33.6
	Ads.	49.87	5.0	25.5	30.5
Copaia	Des.	31.56	6.6	26.2	32.8
	Ads.	45.82	5.3	20.7	25.9
Angelique	Des.	25.04	7.0	23.5	30.5
	Ads.	43.17	5.5	19.6	25.0
Mahogany	Des.	11.92	7.6	16.6	24.3
	Ads.	42.97	5.4	17.6	23.0
Teak	Des.	22.77	6.5	15.7	22.1
	Ads.	50.09	4.7	16.6	21.3
Santa Maria	Des.	10.29	7.9	19.7	27.6
	Ads.	39.52	5.7	17.1	22.8
Kaneelhart	Des.	16.82	7.0	14.8	21.8
	Ads.	49.98	4.6	15.2	19.8
Acetylated white spruce	Des.	67.83	2.4	8.8	11.2
	Ads.	75.59	1.9	7.4	9.3

tent. It appears logical, therefore, to attribute their correspondingly lower fiber saturation points to the displacement of void volume by extraneous materials.

The regression of capillary condensed and total water sorbed on per cent inaccessibility, as shown in Table 3, is significant in desorption but not in adsorption. To account for this observation, the 16 species were segregated into two groups, one characterized by low extractive content (Group A) and the other by high extractive content (Group B).[5] The ratio of capillary-condensed to total water sorbed at saturation during desorption was used as the criterion for separating species into these two groups. It was found that this procedure divided the species into one group (Group B) with a maximum ratio of 0.72 and a second group (Group A) with a minimum ratio of 0.75. Group A ratios were concentrated between 0.76 and 0.80. As a result of this treatment, the regressions of capillary-condensed and total water sorbed at saturation on per cent inaccessibility were not significant with the exception of capillary condensation for Group A in adsorption (Table 5).

[5] Group A includes white spruce, western white pine, ponderosa pine, western hemlock, Douglas-fir, Caribbean pine, basswood, red oak, sugar maple, ceiba, copaia, and angelique. Group B includes western redcedar, redwood, mahogany, teak, Santa Maria, and kaneelhart.

Table 3.—REGRESSION ANALYSIS OF THE RELATIONS BETWEEN SURFACE-BOUND, CAPILLARY-CONDENSED, TOTAL WATER SORBED, AND PER CENT INACCESSIBILITY[1]

Source	D.F.[2]	Desorption: Sum squares	Desorption: Mean squares	Desorption: F ratio	Adsorption: Sum squares	Adsorption: Mean squares	Adsorption: F ratio
Surface-bound water at saturation vs. per cent inaccessibility							
Total	15	3.6341			2.3021		
Slope	1	2.5784	2.5784	34.20	2.0431	2.0431	110.44
Error	14	1.0557	0.0754	** [3]	0.2590	0.0185	**
$100r^2$		70.95			88.75		
Capillary-condensed water at saturation vs. per cent inaccessibility							
Total	15	223.1281			110.8343		
Slope	1	97.4239	97.4239	10.85	11.1350	11.1350	1.56
Error	14	125.7042	8.9789	**	99.6993	7.1214	NS
$100r^2$		43.66			10.05		
Total water sorbed at saturation vs. per cent inaccessibility							
Total	15	205.6852			110.1269		
Slope	1	68.3037	68.3037	6.96	3.6387	3.6387	0.48
Error	14	137.3815	9.8130	*	106.4882	7.6063	NS
$100r^2$		33.21			3.30		
Total water sorbed vs. surface-bound water at saturation							
Total	15	205.6852			110.1269		
Slope	1	13.1176	13.1176	0.95	0.4040	0.4040	0.052
Error	14	192.5676	13.7548	NS	109.7229	7.8374	NS
$100r^2$		6.33			0.37		
Total water sorbed vs. capillary-condensed water at saturation							
Total	15	205.6852			110.1269		
Slope	1	202.5488	202.5488	904.2	107.8410	107.8410	660.4
Error	14	3.1364	0.2240	**	2.2859	0.1633	**
$100r^2$		98.47			97.92		

[1] Excluding acetylated white spruce.
[2] Degrees of freedom.
[3] Level of significance: NS not significant; *significant at 95 per cent level of probability; **significant at 99 per cent level of probability.

Hysteresis is commonly measured by averaging the ratios of the adsorption-to-desorption moisture contents at several selected relative vapor pressures. Results obtained by this method are subject to variation related to the relative vapor pressures at which the ratios are obtained and the limits of accuracy in interpolating moisture contents from the isotherm. The values presented in Table 6 were calculated by integrating the equations for the isotherms between the limits of $h = 100$ and $h = 0$, and obtaining the ratios of the area under the adsorption isotherm to that under the desorption isotherm. These ratios of areas were calculated for the isotherms of surface-bound, capillary-condensed, and total water sorbed.

The two relations, plotted in Fig. 11, indicate that the variation in total hysteresis is virtually independent of hysteresis in surface sorption, but is related to hysteresis in capillary sorption. This is confirmed by the regression analysis given in Table 7. Fifty-four per cent of the variation in total hysteresis is accounted for by the re-

Table 4.—REDUCTION IN THE HYGROSCOPICITY OF WHITE SPRUCE AS A RESULT OF ESTERIFICATION WITH ACETIC ANHYDRIDE

	Untreated spruce		Acetylated spruce		Reduction in hygroscopicity due to acetylation		
	Des.	Ads.	Des.	Ads.	Des.	Ads.	Ave.
Surface bound	7.2	5.6	2.4	1.9	66.7	66.1	66.4
Capillary condensed	23.1	19.4	8.8	7.4	61.9	61.9	61.9
Total water sorbed	30.3	25.0	11.2	9.5	63.0	62.0	62.5

Change in moisture content (untreated minus acetylated)

Moisture content difference		Per cent of total change		
Des.	Ads.	Des.	Ads.	Ave.
Surface bound	4.8	3.7	25.1	23.9	24.5
Capillary condensed	14.3	12.0	74.9	77.4	76.1
Total water sorbed	19.1	15.5	100.0	100.0	100.0

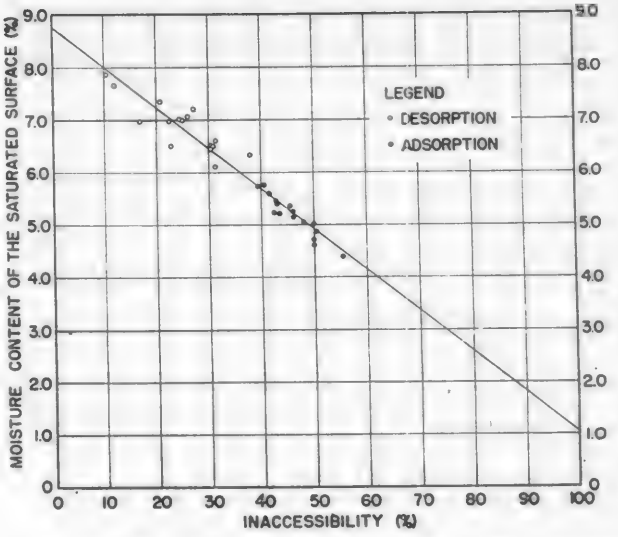

Fig. 10.—Relations between the moisture content of the saturated surface and per cent inaccessibility. The regression line is fitted to all the plotted points without regard to adsorption or desorption.

duced capillary void volume in adsorption. The indications in Table 5 that the relationship between adsorption and desorption may differ for species with high extractive content (Group B) as compared to those of low extractive content (Group A) led to the analysis given in Table 8. The 16 species were divided into two groups, low extractive content and high extractive content, on the same basis as described previously. Eighty-three and 65 per cent of the variability in total hysteresis for Group A and Group B, respectively, is accounted for by hysteresis in capillary sorption. For the latter group, the regression is not significant at 95 per cent level of probability due to the scatter about the fitted line. Consequently, it appears that the presence of extractives appreciably influences the magnitude of hysteresis. Urquhart's explanation (9) that hysteresis is caused by a reduction in the number of surface sites due to lateral hydroxyl-to-hydroxyl bonding upon drying, therefore, requires further qualification. It is also evident that the persistence of hysteresis exhibited by acetylated spruce is not adequately explained in terms of Urquhart's hypothesis.

Discussion

The emphasis in this experiment was twofold, first to evaluate the applicability of the theoretical model, and second, to describe the entire sorption phenomenon as fully as possible.

Table 6.—HYSTERESIS RATIOS IN TERMS OF AREAS UNDER THE ADSORPTION AND DESORPTION ISOTHERMS

Species	Hysteresis ratios in: Surface sorption	Capillary sorption	Total sorption
Softwoods			
White spruce	0.750	0.826	0.790
Western white pine	0.795	0.859	0.831
Ponderosa pine	0.787	0.878	0.837
Western hemlock	0.810	0.883	0.849
Douglas fir	0.802	0.839	0.823
Western red cedar	0.769	0.899	0.835
Redwood	0.724	0.961	0.838
Caribbean pine	0.794	0.840	0.820
Hardwoods			
Basswood	0.788	0.844	0.821
Ceiba	0.774	0.880	0.833
Copaia	0.803	0.790	0.795
Angelique	0.797	0.805	0.801
Mahogany	0.756	0.905	0.831
Teak	0.778	0.903	0.844
Santa Maria	0.769	0.800	0.785
Kaneelhart	0.702	0.869	0.786
Acetylated white spruce	0.829	0.811	0.816

Table 5.—REGRESSION ANALYSIS OF THE RELATIONS BETWEEN CAPILLARY CONDENSED AND TOTAL WATER SORBED AS A FUNCTION OF PER CENT INACCESSIBILITY

Source	D.F.[1]	Desorption Sum squares	Desorption Mean squares	Desorption F ratio	Adsorption Sum squares	Adsorption Mean squares	Adsorption F ratio
Species of Low Extractive Content (Group A)[2]							
Capillary-condensed water at saturation vs. per cent inaccessibility							
Total	9	38.0640			43.5800		
Slope	1	11.7451	11.7451	3.57	23.9461	23.9461	9.76
Error	8	26.3189	3.2899	NS[3]	19.6339	2.4542	*[3]
$100r^2$							
Total water sorbed at saturation vs. per cent inaccessibility							
Total	9	35.3028			68.1395		
Slope	1	5.6683	5.6683	1.53	14.4748	14.4748	2.16
Error	8	29.6525	3.7066	NS	53.6647	6.7081	NS
$100r^2$							
Species of High Extractive Content (Group B)[4]							
Capillary-condensed water at saturation vs. per cent inaccessibility							
Total	9	14.5757			4.2307		
Slope	1	5.2954	5.2954	2.28	1.0945	1.0945	1.40
Error	8	9.2803	2.3201	NS	3.1362	0.78405	NS
$100r^2$							
Total water sorbed at saturation vs. per cent inaccessibility							
Total	9	22.4704			7.7173		
Slope	1	10.2689	10.2689	3.37	3.9342	3.9342	4.16
Error	8	12.2015	3.0504	NS	3.7831	0.94578	NS
$100r^2$							

[1]Degrees of freedom.
[2]Species include white spruce, western white pine, ponderosa pine, western hemlock, Douglas-fir, Caribbean pine, basswood, ceiba, copaia, and angelique.
[3]Level of significance: NS not significant; *significant at 95 per cent level of probability.
[4]Species include western redcedar, redwood, mahogany, teak, Santa Maria, and kaneelhart.

Table 7.—REGRESSION ANALYSIS OF THE RELATIONSHIP BETWEEN THE HYSTERESIS IN SURFACE AND CAPILLARY SORPTION AND TOTAL SORPTION HYSTERESIS[1]

Source	D.F.[2]	Surface sorption Sum squares	Surface sorption Mean squares	Surface sorption F ratio	Capillary sorption Sum squares	Capillary sorption Mean squares	Capillary sorption F ratio
Total	15	0.006891			0.006891		
Slope	1	0.0005298	0.0005298	1.17	0.003733	0.003733	16.55
Error	14	0.006361	0.0004543	NS[3]	0.003158	0.0002256	**[4]
$100r^2$		7.69			54.17		

[1]Excluding acetylated white spruce.
[2]Degrees of freedom
[3]Not significant.
[4]Significant at the 99 per cent level of probability.

Table 8.—REGRESSION ANALYSIS OF THE RELATIONSHIP BETWEEN THE HYSTERESIS IN SURFACE AND CAPILLARY SORPTION AND TOTAL SORPTION HYSTERESIS SEPARATING OUT SPECIES OF HIGH EXTRACTIVE CONTENT

Source	D.F.[1]	Surface sorption: Sum squares	Surface sorption: Mean squares	Surface sorption: F ratio	Capillary sorption: Sum squares	Capillary sorption: Mean squares	Capillary sorption: F ratio
Species of low extractive content (Group A)[2]							
Total	9	0.003280			0.003280		
Slope	1	0.000484	0.000484	1.38	0.002725	0.002725	39.28
Error	8	0.002796	0.0003495	NS[3]	0.000555	0.000694	**[3]
$100r^2$	--	14.76			83.08		
Species of high extractive content (Group B)[4]							
Total	5	0.003611			0.003611		
Slope	1	0.000502	0.000502	0.65	0.002365	0.002365	7.59
Error	4	0.003109	0.000777		0.001246	0.0003115	NS
$100r^2$	--	13.90			65.49		

[1]Degrees of freedom.
[2]Species include white spruce, western white pine, ponderosa pine, western hemlock, Douglas-fir, Caribbean pine, basswood, ceiba, copaia, and angelique.
[3]Level of significance: NS not significant; *significant at 95 per cent level of probability.
[4]Species include western redcedar, redwood, mahogany, teak, Santa Maria, and kanceihart.

Stoichiometric hydrate systems exhibit isotherms that rise in definite vertical steps with increasing vapor pressure. Characteristic isotherms of this type for hydrates have been offered as evidence refuting the formation of stoichiometric hydrates in the cellulose-water system which exhibits smooth sorption isotherms that are free of discontinuities. Consequently, the basic assumption of hydrate formation must be justified in view of this argument. Isotherms for hydrates of low molecular-weight solids are, in fact, stepwise, but for complex, relatively immobile polymer molecules, Langmuir isotherms would be expected as pointed out by Hermans (3).

Hydration is the association of water moclecules to a solid in stoichiometric (molecular) ratios. Cellulose, with its three hydroxyls per glucose anhydride, should form mono,- di-, and trihydrates, resulting in an isotherm with three distinct vertical steps. However, the association of water molecules directly to the cellulose hydroxyls can occur only after the reversible lateral bonds have been ruptured. Increased swelling pressure is required to rupture progressively more stable bonds, and added swelling pressure can be obtained only by increasing vapor pressure. The progressive development of hydrates is a function of swelling, which is a smooth, continuous process with increasing vapor pressure. This is also demonstrated by the shrinkage and swelling of wood with changing moisture content, As a result, the hydrate-water (surface-bound) isotherm is smooth and free of discontinuities.

The magnitude of surface-bound water at saturation (4.5–7.8 per cent) calculated from the theoretical equation is in close agreement with that predicted by Stamm (8) on the basis of the inflection point in sorption isotherms. As may be expected, the prime factor that affects the amount of water directly bound to the surface of wood is the degree of orientation within the cell wall. On the basis of the species tested, there is no significant difference in the amount of surface-bound water sorbed between hardwoods and softwoods. The greater hemicellulose content in hardwoods appears to be masked by the random variation in the crystallinty of the cellulose structure. It may also be that the presumably higher hemicellulose content of hardwoods is an overgeneralization of little real consequence in sorption.

On the assumption that only a monohydrate is formed, no more than one hydroxyl per glucose anhydride is available to sorb water. Nevertheless, an average of 1.8 out of a possible 3 glucose hydroxyls were esterified. The fact that more than one glucose hydroxyl is accessible to acetic anhydride molecules may be explained by the greater swelling of the cell wall in pyridine. Increased swelling of the cell wall liberates more hydroxyls that are accessible to acetic anhydride. This is borne out by the work of Segal, Nelson, and Conrad (6), in which powerful cellulose swelling agents were employed to reduce crystallinity, after which a coincident increase in water-vapor sorption was observed.

The results presented in Tables 2 and 4 indicate that not all of the hydroxyls liberated by swelling in pyridine are accessible to acetic anhydride but are accessible to water molecules. It appears that the swelling and subsequent bulking produced by the acetylation reaction ruptures stable lateral bonds, perhaps in the more oriented regions, of which not all are esterified. Some of these liberated, unreacted hydroxyls would become operative in sorption.

Capillary condensation appears to be the primary factor influencing the observed differences in the hygroscopicity between species. Virtually all of the variation (approximately 98 per cent) in the total water sorbed at saturation is accounted for by the amount of capillary-condensed water in the cell wall. The reduced hygroscopicity of acetylated spruce at saturation is predominantly attributable to the bulking of capillary voids. In view of the fact that the species exhibiting the lowest fiber saturation points are known to have higher extractive contents, it is reasonable to conclude that the reduced capillary condensation is due to the bulking of capillaries by these substances.

Capillary-condensed and total water sorbed do not appear to be dependent entirely on cell-wall orientation as measured by per cent inaccessibility when species known to have high extractive content (Group B) are segregated from those of relatively low extractive content (Tables 3 and 5). This seems to indicate that the influence of cell-wall orientation is masked, in part, by the presence of non-cellulosic substances within the cell wall. This is in contrast to the results obtained by Segal, Nelson, and Conrad (6), who studied the effect of cellulose crystallinity on the sorption of water at 81 per cent relative humidity. At this high relative humidity, capillary condensation would be expected to make the larger contribution to the total water sorbed. They found that the total water sorbed by pure cellulose at 81 per cent relative humidity declines lineraly with increasing crystallinity.

The results of this study show that hysteresis varies significantly between species. Urquhart's explanation for hysteresis attributes the observed phenomenon to reduced hygroscopicity due to lateral hydroxyl bonding upon desorption to dryness. However, the results shown in Fig. 11 and Tables 7 and 8 indicate that hysteresis is not merely the product of a reduced number of sorption sites during adsorption, but is predominantly influenced by capillary condensation. A more explicit explanation will be proposed here, one which is fundamentally similar to that published by Barkas (1).

Cellulose is formed in water solution from glucose and is precipitated on the cell wall, forming its basic structure. At this point, portions of the cellulose in the cell wall are highly dispersed in water, thus lateral cohesive forces are not fully developed due to interfering water molecules. Upon initial drying from the green condition, the gel becomes more compact as water is removed, permitting a more fully developed, laterally cohesive aggregate to form. The hydroxyl-bond cross-linkages that form early in initial drying are stable due to the changes in configuration that occur while the gel is still highly dispersed and relatively mobile. The series of equilibria then descend the curve AB shown in Fig. 2.

As the first hydroxyl bonds form, mobility is reduced. Further removal

of water, which is more intimately associated with cellulose, produces distortion in the gel due to shrinkage. Consequently, strains develop in the hydroxyl-to-hydroxyl bonds that form late in the equilibrium series along curve BC. In the completely desiccated state (point C), cellulose achieves its highest degree of orientation. Upon readsorption from the dry state, the unbonded and weakly bonded hydroxyls attach water molecules first. At any relative vapor pressure, the gel retains some of the aggregation acquired in drying, and hence approaches saturation at a lower limit (point D) than attained in subsequent desorption. Further reversible dispersion is accomplished as the isotherm rises more abruptly in the vicinity of vapor saturation to the desorption saturation limit (point E).

As a result of this behavior, hysteresis is merely the outgrowth of two series of equilibria attained by the cellulose, starting in one instance from a dispersed state, and in the other, from a more highly aggregated state. At both extremes, drastic treatment is necessary to produce the gel configuration that is partly developed throughout the preceding series of equilibria. This is evidenced from the investigations of Urquhart and Eckersall (10) and Knight and Pratt (4), where the magnitude of hysteresis increased as the degree of desiccation or dispersion increased. From this, these researchers concluded that the maximum hysteresis isotherms define an area of all possible equilibria that the material can attain at that temperature. The particular equilibria produced are thus an outgrowth of the history of the material, or more precisely, the degree of aggregation or dispersion that was previously attained.

A comparison between woods of low extractive content and those of high extractive content lends support to the explanation given above. The relationship between hysteresis is capillary sorption and total sorption hysteresis differs markedly between these two groups. This is probably due to the bulking of amorphous void volume by the extractive materials. Since these materials infiltrate the heartwood when the constituents of the cell walls are highly dispersed and mobile, these bulking agents inhibit the subsequent development of aggregation and also reduce void volume. Consequently, the glucose anhydrides within the cell walls of these species are more accessible than those in the relatively extractive-free woods. This is shown in Table 2 for redwood, western redcedar, mahogany, teak, Santa Maria, and kaneelhart, Inaccessibility in desorption is consistently lower for these woods than for the remaining species. Thus, more accessible, active surfaces are present in these woods to develop aggregation upon drying.

The persistence of hysteresis in acetylated white spruce is suggested to be due to the freeing of formerly stable hydroxyl bonds as a result of the greater swelling in pyridine. The liberated hydroxyls, as previously indicated, probably become active in sorption and are operative in the development of aggregation to produce hysteresis. The reduced magnitude of hysteresis in acetylated spruce (Table 6) is proposed to be the result of two factors. First is the reduction in the number of accessible hydroxyls as indicated by the per cent inaccessibility shown in Table 2. The second is the bulking action of the ester, which reduces the degree of aggregation that may be attained in drying.

Conclusions

The analysis of experimental data in terms of the theoretical model derived by Hailwood and Horrobin is found to provide a description of the sorption process that is in basic agreement with the results of previous investigations. In view of the apparent applicability of the solid-solution model, some fundamental qualifications of the sorption characteristics of wood are offered.

The assumption that water is hydrated directly to cellulose in a stoichiometric ratio is considered to be perfectly plausible when viewed in the light of cellulose structure. Postulating that only a monohydrate is formed is shown also to be valid. It is apparent from the results obtained that the magnitude of hydrate formation is dependent upon the degree of orientation within the cell wall. The observed independent between the magnitude of water condensed in capillaries and cell-wall orientation is suggested to arise from the bulking of capillaries by extraneous infiltrants. Furthermore, the presence of these extraneous infiltrants in the cell wall seems to have little if any effect on surface sorption.

Hysteresis is shown to be primarily a capillary void-volume phenomenon although its basic mechanism is most reasonably ascribed to lateral bonding. An explanation for the observed hysteresis is offered that emphasizes the development of compactness or aggregation upon the removal of water. Hysteresis is then described as a series of equilibria attained by the gel, in one case starting from a relatively dispersed state, and in the other from a relatively compact state.

Analysis of the hysteresis phenomenon is considerably improved when species known to have extraneous infiltrants in the cell wall are treated separately. From this it is suggested that the presence of these substances in the cell wall appears to exert a marked influence on hysteresis.

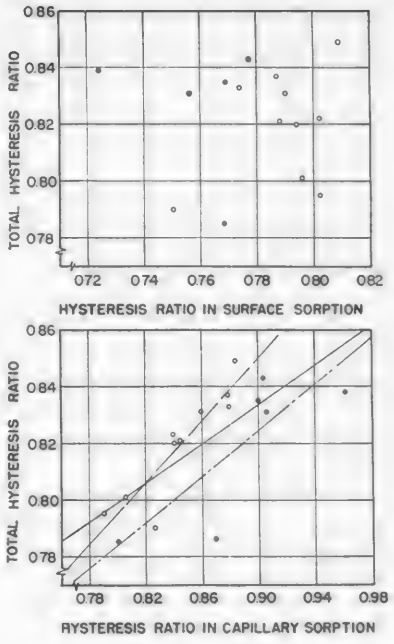

Fig. 11.—Total hysteresis ratios plotted against the hysteresis ratios obtained from the surface-bound and capillary-condensed isotherms. All the ratios were calculated in terms of areas under the isotherms. Open data points are for species of low extractive content; closed points are for species of high extractive content.

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Electron Microscope Studies of Pit Membrane Structure

IMPLICATIONS IN SEASONING AND PRESERVATION OF WOOD[1,2]

Electron microscopy reveals details not resolved by light microscopes. The differences between bordered pit membranes in conifers and hardwoods is clearly demonstrated. Since these structures influence movement of liquids in wood cells, they are fundamental in seasoning and preservation of wood.

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ACCORDING TO THE NEW Glossary of Terms published recently by the International Association of Wood Anatomists (1)[2], a pit is defined as a recess in the secondary wall of a cell, together with its external closing membrane. On this basis, the tissue surrounding this gap is not an integral part of the pit. Nevertheless, the variation in pit shape caused by the orientation of microfibrils in the secondary wall around the pit is commonly used as a feature for the separation of species in wood identification. The nature of the pit membrane, which is really primary wall, has greater significance in tree physiology, wood seasoning, and wood preservation because its construction necessarily influences the movement of liquids from one cell to another. In hardwood trees, the presence of vessels for the movement of liquids in the xylem portion of the stem could reduce the importance of the role of the pit membranes, but in conifers the vertical translocation of materials in the wood is dependent upon lateral movement from one tracheid to another through the bordered pit pairs.

Although the gross features of pit structure can be seen quite readily with a light microscope, the membrane features are too fine to be well resolved by optical means. Therefore, the true nature of the membrane in pit pairs has been a point of controversy for many years. Photomicrography with ultra-violet light overcomes, to some extent, the physical limitations on resolving power imposed by the relatively long wave-length of visible light, but even by this means resolution cannot exceed 0.1 micron. Marts (14) used phase-contrast microscopy for the examination of Douglas-fir pit membranes, and a photomicrograph taken by this method revealed exceptional detail for light microscopy. Experiments on the movement of fine particles in suspension through wood provided additional data, which helped to develop a hypothesis on pit membrane structure.

The introduction of the electron microscope to wood structure research has made it possible to resolve structures one hundred times smaller than could be distinguished clearly with the light microscope, due to the short wavelength of the electrons used as a source of illumination in this instrument. Consequently, much new information of value to the wood-using industry can now be made available.

Historical Background

The work of Bailey (2) in 1913 provided some of the first evidence of the true nature of the bordered pits in coniferous tracheids. His experiment on the penetration of finely divided carbon particles through green and seasoned wood indicated that the membrane had openings that permitted the passage of the particles from one cell to another. Photomicrographs of the bordered pits from the treated specimens showed that the membrane consisted of a central thickened portion from which dark lines radiated, caused by the carbon particles at the membrane openings. Until the report of this work, physiologists and anatomists felt that the cambial wall or primary membrane enclosed tracheids completely. Thus, bordered pits might

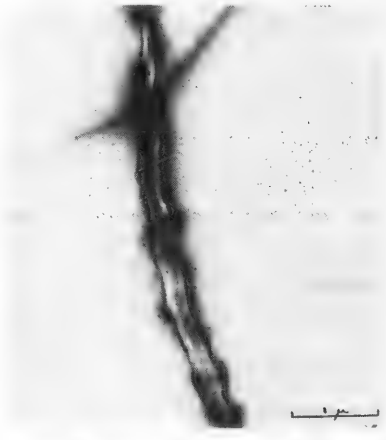

Fig. 1.—Electron micrograph of ultra-thin section through the torus of a bordered pit pair of eastern white pine, *Pinus strobus* L. The dark line through the middle of the tissue is the middle lamella, while the lighter areas on either side of it are primary wall thickenings. *Magnification:* 12,000X.

[1]Honorable mention, 1958 Wood Award Competition. Presented at Session XVI, General, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

The Author: Wilfred Côté holds a BS in forestry from the University of Maine, an MF in wood technology from Duke University, and a PhD from the New York State College of Forestry at Syracuse. Côté set up the electron microscopy laboratory at Syracuse, and developed the techniques described in the article.

surround a thin area of the primary membrane, because it was obvious that water could move from cell to cell and a semi-permeable membrane would allow such movement.

A diagrammatic drawing of the structure of a coniferous pit membrane that Bailey included in his article remains amazingly accurate today. The evidence supplied by the electron microscope merely confirms and refines the theory advanced by him. However, many workers never fully accepted the idea that a perforated pit membrane was a natural condition, but felt that the slit-like openings were probably microscopic seasoning checks in spite of Bailey's carefully controlled experimental work.

Liese and Fahnenbrock (12) proposed modifications to Bailey's theory on the basis of electron microscopic evidence. According to their "Faden structure" principle, the openings around the torus in the coniferous pit membrane were as large as 1 micron wide by 4 microns long. Frey-Wyssling and Bosshard (5) claimed that the openings suggested by Bailey's early work were actually occluded by an "ultrafilter" of cellulose microfibrils. Bailey contributed to the clarification of these contradictory findings in an article (3) in which he pointed out that careful sampling techniques for the investigation of fine structure in wood must be used in connection with electron microscopy just as in light microscopy, and that the differences reported in the literature were probably due to this oversight. Both of these extremes have since been modified on the basis of more extensive work. Liese (10) conducted an experiment similar to the one reported by Bailey 40 years previously, except that he refined the controls by making electron microscopic measurements of the titanium oxide particles in suspension before and after filtration by the wood through which the liquid was passed. He found that particles as large as 0.2 micron passed through the membranes of several coniferous species.

Present-day concepts of the structure of the pit membrane in coniferous bordered pits have been well substantiated. The work of Liese, Frey-Wyssling, and Harada with their respective co-workers necessarily gives a good cross-section of species studied and trees sampled. Furthermore, both ultra-thin sectioning and replica techniques have been applied to the problem, thus providing confirmation by very different preparation methods. Within this study, replica and pseudo-replica methods were used and, since the latter method is different from those used by other workers, results from its use provides additional sup-

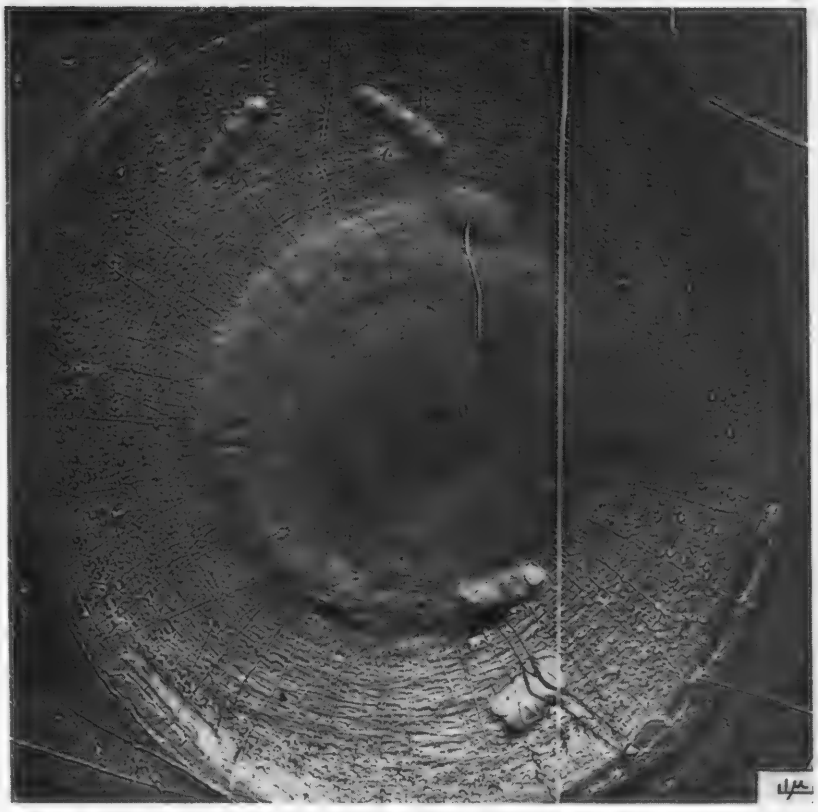

Fig. 2.—Electron micrograph of a bordered pit in ponderosa pine, *Pinus ponderosa* Laws., with bacterial bodies enmeshed in the strands of the supporting membrane. Note the microfibrillar orientation in the torus and the wart-coated pit border. Carbon replica, chromium preshadowed. *Magnification: 5000X.*

Fig. 3.—Electon micrograph of a portion of a pit membrane from a bordered pit pair in the heartwood of redwood, *Sequoia sempervirens* (D. Don) Endl. The embrittled and broken supporting strands are covered with nodular growths. Actual membrane, chromium shadowed. *Magnification: 12,700X.*

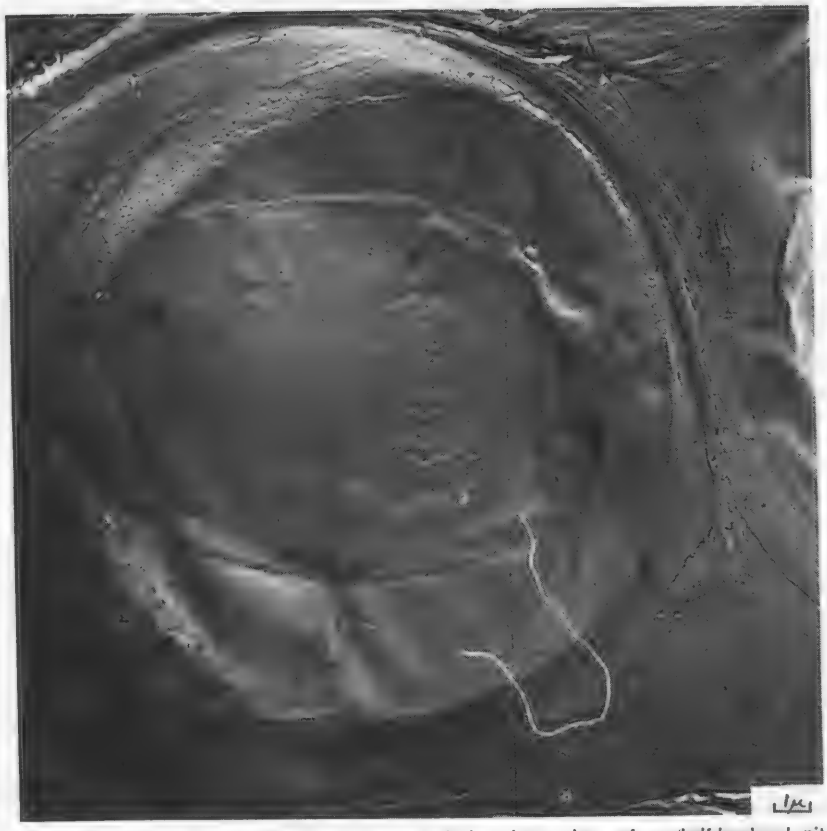

Fig. 4.—Electron micrograph of the surface of the pit membrane in a half-bordered pit pair in eastern white pine, *Pinus strobus* L. Note the microfibrillar organization and the impression of the over-hanging border. Carbon replica, pre-shadowed witth chromium. *Magnification: 5000X.*

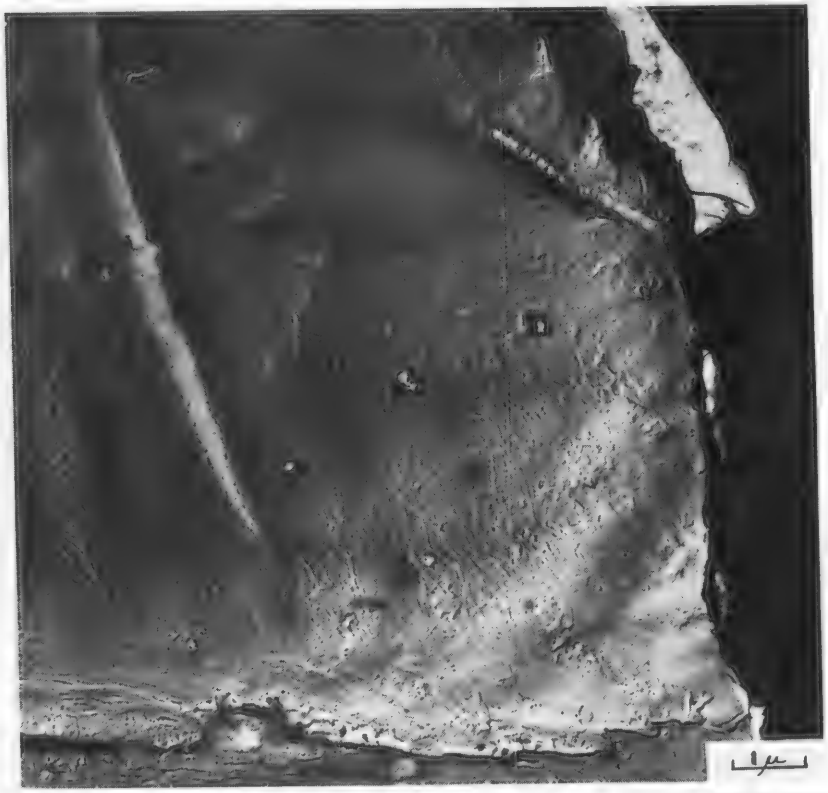

Fig. 5.—Electron micrograph of a portion of the surface of a pit membrane from the same specimen as Fig. 4. Microfibrillar structure of the window-like pit pair membranes is revealed at the margin of the membrane where the coating layer is thinner. Carbon replica, pre-shadowed with chromium. *Magnification: 10,500X.*

port because of the agreement with the findings of other workers.

The structure of simple and half-bordered pit membranes in conifers has received relatively little attention, presumably because their importance has not been considered as great as the bordered pits. Harada (7) reported that his investigation of xylary ray cells confirmed what had previously been suspected. That is that the simple and half-bordered pit pairs do not have thickened membranes corresponding to the torus in bordered pit pairs. He also pointed out that these membranes are homogeneous, unperforated, and non-fibrillar. A later paper by Frey-Wyssling and Co-workers (6) suggests that the half-bordered pit membranes in *Pinus* are fibrillar and have the dispersed texture of the primary wall.

Coniferous woods are composed largely of tracheids whose general configuration varies little between species. Hardwoods contain a variety of cell types, and their distribution and organization changes markedly between genera and even between species (4). Therefore, the study of hardwood cell walls and pit membrane structure has been avoided deliberately because of the relative complexity of interpretation of electron micrographs of this group. Only in recent months, after preparation techniques for coniferous woods were developed to a satisfactory point, has there been any publication on hardwood pit membrane structure based on electron microscopy. Liese (11) investigated a number of species and Harada and co-workers (9) published a comprehensive summary of their studies, which included a few electron micrographs of hardwood pit membranes. In both of these cases, the results are in general agreement with the findings of this study.

Specimen Preparation Techniques

Most of the wood specimens examined with the electron microscope in this study were prepared by the replica or the pseudo-replica method. These techniques were adopted after experiments with ultra-thin sectioning proved to be generally less satisfactory for wood because of artifacts, which are deformations in the material produced by exceeding the critical value for shear stress.

A replica is a facsimile of a specimen surface in a material which is transparent to the electron beam by virtue of its relative thinness. Since wood blocks, or even wood sections of greater than about 1/20-micron thickness, are opaque to the electron beam, replica technique is a useful and satisfactory indirect approach for the study of this material. The method devel-

oped in this investigation involved pressing the surface of a freshly split wood specimen into a heat-softened sheet of thin polystyrene film. The specimen was stripped from the plastic after cooling had hardened the film. If good contact was made between the specimen and the film, and if the softening temperature was high enough to insure sufficient flow of the polystyrene, thin lamellae of wood sometimes adhered to the hardened plastic when it was peeled from the wood. This phenomenon was the basis for the development of pseudo-replication. The extent of wood adhesion was an undeterminable and accidental occurrence, and not all areas of the plastic film were covered with wood fragments. Where only an impression was left in the polystyrene film, the true replicas resulted.

Shadowcasting the specimen by the evaporation of a heavy metal at an angle to the specimen surface is a step included in the preparation technique for the enhancement of image contrast (15). Chromium and uranium were the metals used in the shadowing work for this study. This procedure, and the evaporation of a carbon film, were carried out with high-vacuum evaporation apparatus. The carbon film with its pre-shadowed metal form the final replica, which is introduced into the electron microscope column for examination. The removal of the initial plastic film from the carbon was the final preparation step, and was carried out in a solvent boiler. Benzene was the solvent found to be most effective for the safe and rapid removal of the polystyrene.

In the areas of the original replica which were plastic film impressions, only pre-shadowed carbon film remained to represent the original wood surface. Where thin lamellae of wood accidentally adhered to the polystyrene, these were transferred to the carbon upon removal of the plastic in the solvent boiler. Thus, the specimens that were finally studied microscopically consisted of actual wood material and carbon film replica.

Discussion

In the majority of cases, a gap in the secondary cell wall occurs directly opposite one in the wall of the adjacent cell. Therefore, the correct nomenclature for two such connecting recesses is a pit pair. This term is qualified to indicate the nature of the pits forming the pair. For example, it is termed simple pit pair when the canal through the secondary wall of both cells does not taper from the lumen to the membrane. Pits that have overhanging borders enclosing a pit cavity are typical of those which oc-

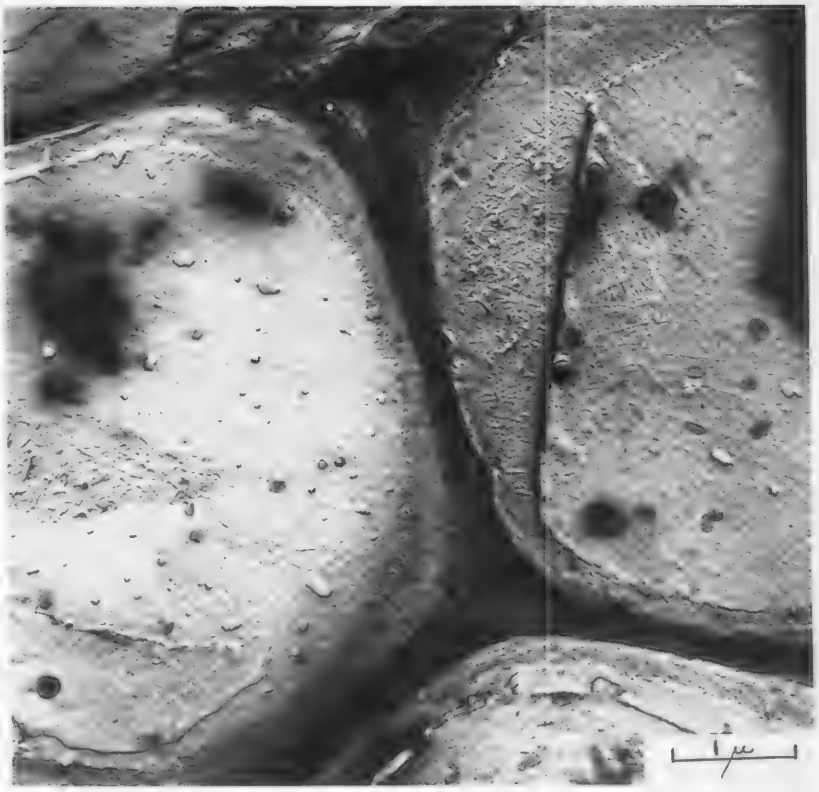

Fig. 6.—Electron micrograph of portions of four intervessel pits in basswood, *Tilia americana* L. The primary wall layer was ruptured at the inter-pit zones. The edge of the membrane at right center was folded over during processing, revealing its under-surface and an imprint of microfibrils in the middle lamella. Carbon replica, chromium pre-shadowed. *Magnification: 17,500X.*

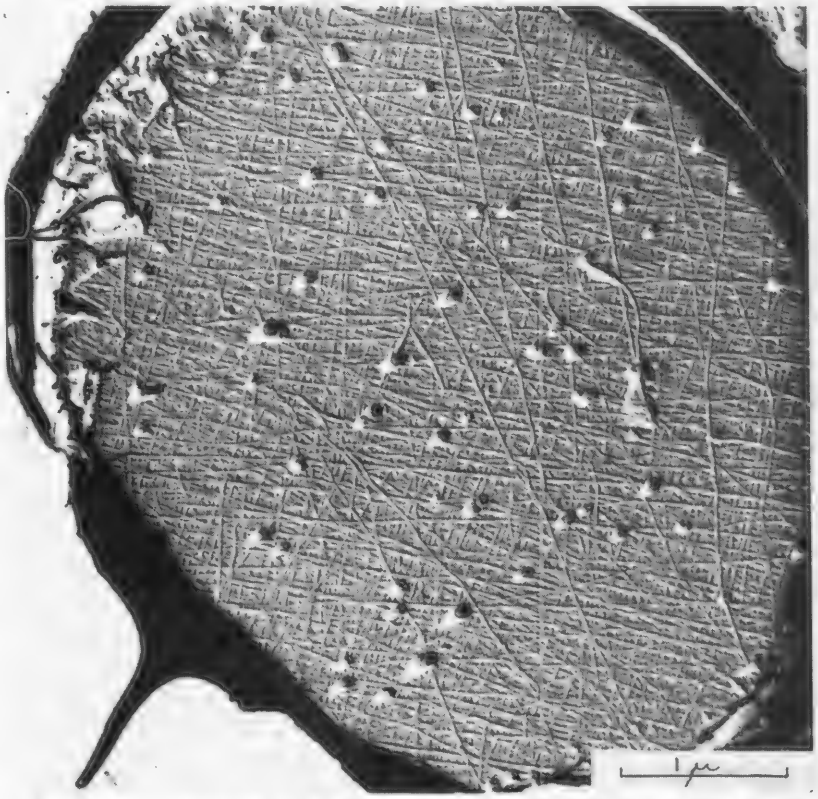

Fig. 7.—Electron micrograph of the surface of a pit membrane from an intervessel bordered pit pair in basswood, *Tilia americana* L. Note the crossed lamellar structure and the particles which presumably were filtered out of the liquid moving through the membrane. Pseudo-replica, uranium shadowed. *Magnification: 24,000X.*

cur between coniferous tracheids. Two such pits in series are termed a bordered pit pair, whereas a simple pit and a bordered pit in series is called a half-bordered pit pair. This terminology is applied to both hardwoods and softwoods.

Since each cell in wood is enclosed in a cambial wall, each pit has a closing membrane at its outer aperture, that is, at the primary wall. It follows that two primary walls cover the opening in a pit pair. The presence of an intercellular layer joining the primary walls of adjacent cells has long been recognized so that the "compound pit membrane" can be considered to consist of two primary wall layers with a thin middle lamella sandwiched between them. This was, in fact, the structure that was accepted by most workers even after the report of Bailey's experiments mentioned earlier. Natural perforations were not believed to exist in any of the pit membranes until recent electron microscopic evidence was found to be more convincing, and doubt exists in some quarters even today.

Results

The Coniferous Bordered Pit Membrane: This investigation has confirmed the most recent concepts on coniferous pit membrane structure proposed by Frey–Wyssling (6), Liese (10, 13) and Harada (8, 9) and their respective co-workers. For the majority of cases, the central area of the closing membrane is furnished with a thickened circular plate or torus. This structure is supported by strands of microfibrils in such a way that the torus may be displaced against the inner surface of the border of either cell, thus acting as a value in closing the aperture. The torus was found to be of sandwich construction, the thin middle lamella being held between, or holding together, the two primary wall thickenings. This is shown in Fig. 1, an ultra-thin section through the torus of a bordered pit pair in eastern white pine, *Pinus strobus* L. The dark line through the middle of the tissue represents the middle lamella, while the lighter areas are the fibrillar thickenings of the primary walls of two contiguous tracheids.

A face view of a pit torus and supporting membrane is shown in Fig. 2. The supporting membrane consists of a network of cellulosic filaments radiating from the torus to the margin of the pit cavity. The filaments appear to arise from the two faces of the torus and to be made up of microfibrils joined into coarser strands. There appears to be no trace of middle lamella in this portion of the membrane. This agrees with Bailey's claim (3) that the pectic constitutents of the pit membranes are dissolved during the maturation of the cells with no apparent hydrolysis of the cellulose microfibrils. It is very clear that the supporting membrane is porous and that relatively large particles could move through the pit quite readily. Fig. 2, an electron micrograph of a carbon replica, was selected to demonstrate that larger bodies could get enmeshed in the membrane, however. Bacteria were discovered in the pit cavity of a ponderosa pine (*Pinus ponderosa* Laws.) bordered pit pair, some caught in the strands of the membrane and one under the edge of the thin and flexible torus. This pit would be considered to be in aspirated condition since the torus is pressed against the aperture. This condition existed in all cases where replicas of radially-spit specimens were prepared. The pressure required to make the initial impression in softened polystyrene film was considered to be sufficient to create this artifact. Note that the pit border behind the membrane shows circular orientation of the microfibrils, and that it is coated with a warty granulation.

It was observed that, in the heartwood of certain species, the supporting membrane appeared to be less porous than in the sapwood because of the presence of nodules on the strands. There was also evidence of embrittlement of the membrane in such cases. Fig. 3 is a pseudo-replica, a portion of the actual pit membrane from a bordered pit pair of redwood, *Sequoia sempervirens* (D. Don) Endl., heartwood.

The Coniferous Half-Bordered Pit Membrane: It was readily understood why the membrane between a parenchyma cell and a tracheid was not thought to be fibrillar. No evidence of microfibrils could be found initially, but when the window-like pits in eastern white pine were examined, a trace of microfibrillar structure was noted near the margins of the large membranes. Further study of this species revealed that the membrane was coated with a very smooth layer of material, which masked the microfibrils of the primary wall. These findings are illustrated in Figs. 4 and 5. Fig. 4 shows one pit and part of another with microfibrils discernible through some portions of the coating layer. Note the lack of a torus or central thickening, although an impression of the overhanging border can be observed. Note also that the membrane is imperforate. Fig. 5 shows the edge of a window-like pit membrane photographed at higher magnification. In this case the microfibrils can be readily seen. It should be noted that Harada's latest publication (9) indicates that he has reversed his opinion on this point, and is in agreement with the findings of this study.

Hardwood Pit Membranes: As far as could be determined from the various species examined in this study, all of the pit membranes were very similar in construction. Both simple and bordered pit pairs have membranes consisting of two primary wall layers with a thin intercellular layer between them. No torus was observed, although on occasion the center of the membrane appeared to be thickened because of the accumulation of filtered material. No openings resolvable with the electron microscope were observed on the membrane surface, but the nature of the structure can best be described by referring to Figs. 6 and 7.

Fig. 6 is an electron micrograph of the surface exposed by splitting a piece of basswood, *Tilia americana* L. Portions of four intervessel pits near the intercellular zone are shown. The primary wall that should extend across the entire surface has been ruptured at the regions between the pits, leaving isolated patches of microfibrillar wall covering the middle lamella. The edge of one of the primary wall patches was folded over in processing, thus revealing an imprint of microfibrils on the middle lamella.

Fig. 7 is a similar pit membrane from the same species shown at slightly greater magnification and revealing the microfibrillar organization that has been reported to be typical of the primary wall. The particles on the membrane are presumed to have been filtered by the membrane.

Conclusions

The findings of this investigation and the confirmation of pit membrane structure previously reported by other workers suggests certain implications in the seasoning and preservation of wood.

The difference in penetrability between coniferous sapwood and tyloses-free hardwood is related to the structure of the elements composing these woods. In hardwoods, the tube-like vessel segments have perforated ends and since they are joined end-to-end at their perforation plates, lengthwise penetration is relatively easy. However, much of the wood is not directly penetrated since lateral movement from the vessels into other types of cells surrounding them is limited to diffusion through the pit membranes described above. Particles suspended in the preservative solutions must be filtered out as the liquid diffuses through the membrane.

Penetration in coniferous woods is dependent upon lateral movement through the bordered pit pairs between tracheids because the tracheid ends are imperforate and the cells are not joined end-to-end (16). In spite of this seemingly devious path, most of the wood can be penetrated directly because of the openings in the bordered pit membranes.

The presence of tyloses in hardwoods is known to inhibit the penetration of preservatives because such structures occlude the main avenues of movement. It will be necessary to investigate coniferous woods that are particularly difficult to penetrate to determine whether the encrustation of the membrane in heartwood is the controlling factor. The electron micrograph in Fig. 3 indicates that this condition would probably affect penetrability. Its greatest significance would be in pressure treating, because the ease of penetration varies as the fourth power of the diameter of the apertures [3] in the material being treated. Therefore, the reduction of opening size in coniferous pit membranes by one-half would increase the resistance to penetration through such an aperture by 16 times.

The importance of pit membrane structure in seasoning is not so great because water is the moving medium. Since water can diffuse readily through thin membranes as it does in the living tree, differences in structure are not so critical. However, in woods where collapse is an important seasoning problem, the sizes of the openings in the closing membrane are significant. According to the tension theory of collapse, the forces that cause this failure increase as the sizes of these openings decrease. This relationship can be applied to the reduction in aperture size caused by the encrustation of pit membranes and the possible increased susceptibility to collapse due to this phenomenon.

[3] Poiseuille's Law states that the rate of penetration of a liquid through a small constriction under hydrostatic pressure is proportional to the fourth power of its diameter.

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Strain Behavior of Wood

SUBJECTED TO REPETITIVE STRESSING IN TENSION PARALLEL TO THE GRAIN[1,2]

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The effect of 100 stress cycles on strain behavior is discussed. It appears that the creep-initial strain relationship is satisfactorily described by an exponential regression within the range of initial strains studied. Ultimate tensile strain and stress are apparently unaffected by this number of stress repetitions at the observed stress levels. It is indicated that the creep-cycle number relationship may be similar for the three species studied, and that creep may be dependent primarily upon initial strain.

IT HAS LONG BEEN ESTABLISHED that considerations of the strain behavior of wood must take into account not only the effect of the imposed load, but, in addition, the effect that time has on this load-strain relationship. In past years, many workers have recognized the strain-time relationships for wood, and have attempted to study them by observing the effect of rate of loading, sustained loading, and fatigue on the properties of wood, particularly with respect to changes in Young's modulus, creep, set, and ultimate strength. For the most part, these studies have been conducted in bending or compression. As a result, only a meager amount of information has been reported on the tensile properties of wood, in particular the strain behavior under repeated loading.

In view of the relatively small quantity of cyclic stress data for wood, a brief review of the strain behavior exhibited by other cellulosic high polymers can serve as excellent background

[1] Honorable Mention, 1958 Wood Award competition.

[2] This research is part of a comprehensive study being conducted at the Yale School of Forestry in cooperation with the Office of Naval Research, Dept. of Navy, under Contract Nonr 609(13), Project NR 330–001, Properties of Tropical Woods.

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material (1,5,8,10)[3]. The strain-time relationship can be observed most clearly after the application of a constant load to a cellulosic high polymer. Following an initial instantaneous extension, an increase in deformation occurs. This increase, called creep, takes place at a decreasing rate, and for long periods of time it can be described by the equation

$$e = e_i + at + b \log t$$

where e is the total strain at time t. e_i is the initial strain, and a and b are variables dependent on the load, characteristics of the material, and experimental conditions. The creep rate, expressed by the variable b for a cellulosic high polymer, has been found to increase with increases in load, temperature, and moisture content. At loads below the yield point [4] the total strain becomes virtually constant with time.

Immediately upon release of the applied load, an instantaneous recovery occurs. Some residual deformation remains, however, the size of which is dependent on the magnitude and duration of the applied load. This residual deformation tends to decrease with time, rapidly at first, then decreasing gradually. Eventually the material may return to its original dimensions. The observed creep behavior is not, then, plastic in nature, but rather the result of a delayed elasticity. In many instances, recovery of the residual deformation is not complete. Consequently, distinction is made between creep which is recoverable and that which is not. The former is termed primary creep, and the latter secondary creep, or more commonly, set.

If a cellulosic high polymer material that exhibits set after loading is reloaded several times to the same deformation without failure, it is found that the set approaches a constant limit. When set becomes constant, the polymer is said to be mechanically conditioned, and will behave as an ideally elastic material, exhibiting only primary creep at loads up to the conditioning load. This conditioned state is not permanent, and in cellulosic materials is lost upon swelling in water. Upon loading after this treatment, secondary creep will once more take place.

If the load-deformation pattern of a mechanically conditioned cellulosic high polymer is observed under conditions of load application and release at a constant rate, it is found that a hysteresis loop is formed such that the strain for a given load is greater upon releasing the load than on applying it. Neither portion of this hysteresis loop is strictly linear. Both the formation of this loop and its non-linearity are the result of the delayed elastic effects of creep and creep recovery. The area of the loop is dependent on moisture content, temperature, and both the magnitude and the rate of loading. If the material has not been mechanically conditioned, a hysteresis loop is formed, but it will not close at zero load due to the increased increment of set. As might be expected, all of these phenomena have been observed to a limited degree in wood subjected to stresses in bending, tension, or compression.

In a repetitive stressing test, one load cycle follows immediately upon another. Fatigue tests are of this type, but, for the most part, they are concerned only with estimations of fatigue life rather than changes in strain behavior during the test. Fatigue life is considered to be the number of stress cycles that will cause failure under a given set of test conditions. In general, it has been observed that the fatigue life decreases with an increase in the cyclic stress. Most fatigue investigations on wood have been conducted in bending; Lewis (9) however, reported that the fatigue limit of Douglas-fir and white oak in tension parallel to the grain is approximately 50 per cent of the static tensile strength at 30 million stress repetitions.

Ivanov (6) has reported the results of repetitive tests in tension parallel to the grain for loads delivered at a constant rate of loading to successively higher stress levels. Failure tended to occur not at the maximum stress, but at a lower stress corresponding to a greater deformation due to the occurrence of creep. Ivanov concludes ". . . consequently, the condition of failure of the wood is not the stress, but the deformation equal to the limiting deformation of plastic flow".

In repetitive tests of these types, creep, recovery, hysteresis, and mechanical conditioning interact in a complex manner. It is this interaction and the effect upon the strain behavior of such conditions as stress level and moisture content that is presently under study. This report presents some results of this investigation; namely, the effect of stress level on the aforementioned behavior for three tropical species stressed in tension parallel to

[3] Numbers in parentheses refer to the Literature Cited at the end of this paper.

[4] The yield point of a cellulosic high polymer is generally comparable to the limit of proportionality of the stress-strain relationship for wood.

Table 1.—SUMMARY OF TEST DATA FOR CEIBA

Specimen number[1]	Specific gravity (O.D. Vol.)	Moisture content, (Per cent)	Assumed stress level[2]	Ultimate tensile strength (psi)	Maximum strain[3] (Micro-in./in.)	Initial strain[4]	Modulus of elasticity (1,000,000 psi) First cycle	Modulus of elasticity (1,000,000 psi) Last cycle	Creep (Micro-in./in.) at cycle numbers 10	20	50	100
A 1	0.26	13.9	30	3430	7170	3746	0.5004	0.4915	66	87	105	125
A 2	0.32	14.3	40	7250		3344	0.7819	0.7776	52	60	80	100
A 3	0.31	13.7	50	7750	9940	3945	0.8028	0.8194	65	75	135	155
A 4	0.29	16.2	60	4960	9660	6615	0.5758	0.5941	235	375	695	1145
A 5	0.27	14.3	70	6770	12440	6420	0.5991	0.6095	200	300	510	830
A 6	0.28	15.4	80	7130	12070	6923	0.6419	0.6689	238	357	686	1155
Avg.	0.29	14.6		6220	10260		0.6503	0.6602				
B 1	0.20	11.2	30	2430	7790	3130	0.3582	0.3582	57	75	111	132
B 2	0.20	12.5	40	2570	8220	4030	0.3443	0.3426	108	172	304	428
B 3	0.24	10.4	50	4110	8110	3360	0.5286	0.5213	25	45	105	149
B 4	0.23	11.5	60	3570	8430	4640	0.4478	0.4654	115	175	235	325
B 5	0.24	12.9	80	3620	8530	5870	0.5091	0.4912	280	392	602	
Avg.	0.22	11.7		3260	8220		0.4376	0.4357				
C 1	0.21	11.0	30	2570	7100	2770	0.4161	0.4207	60	84	132	144
C 2	0.24	11.4	40	2200	7300	4450	0.3280	0.3280	96	128	180	264
C 3	0.23	13.4	50	2850	9460	5220	0.3356	0.3356	144	212	376	592
C 4	0.30	14.9	60	3810	9060	4740	0.4452	0.4429	110	150	260	333
C 5	0.26	11.8	70	4070	8240	4650	0.5235	0.5216	114	150	222	312
C 6	0.25	11.0	80	3690	8020	5590	0.5073	0.5073	132	210	354	552
Avg.	0.25	12.2		3200	8200		0.4259	0.4260				
Control averages												
A series	0.29	14.9		6360	10510							
B series	0.22	11.9		3520	8970							
C series	0.25	12.3		3510	7940							

[1] The letters A, B, and C represent the three series of specimens.
[2] Percentage of average ultimate tensile stress of control specimens.
[3] Strain at failure after 100 stress cycles; creep strain included.
[4] Strain at the assumed stress level on the first cycle.

the grain. The three species include ceiba (*Ceiba pentandra*), determa (*Ocotea rubra*), and kaneelhart (*Licaria cayennensis*).

Test Procedure

Three flat-sawn planks were selected from two different logs for all three species, and 20 defect-free rough specimen blanks, ½ by 1½ by 20 inches, were sawn from each of these planks according to a scheme of tangential- and end-matching. Care was taken to insure that the 1½ inch dimension of each blank was perpendicular to the plane of the growth rings. Each such group of 20 blanks was designated as a series. Material that exhibited a slope of grain greater than 1 in 28 on the radial surface was discarded. The slightly interlocked nature of all three species made it necessary to accept material with a slope of grain greater than this on the tangential surface.

The standard tension parallel to grain test specimen as described in ASTM designation D 143–52 (2) was used in the study. Because of the difficulty in grain-matching 20 1 by 1-inch specimens, it was necessary to resort to laminating a ⅜ by 1¼ by 19-inch piece to each side of the specimen blank of the same size. Side pieces were cut from the same species for this purpose, but no consideration was given to matching or growth-ring orientation. Each laminated unit was machined to the standard specimen size such that the critical section of each specimen, where strain measurements were taken, consisted entirely of matched material. During machining, the material was maintained at a moisture content of approximately 12 per cent. After final machining, the specimens were stored in a chamber over a saturated sodium nitrite solution. The chamber was maintained at a temperature of 90± 1½° F. At this temperature, the atmosphere above the solution provided a nominal 12 per cent equilibrium moisture content in the wood specimens.

Strain was measured with SR–4, type AD–1 strain gages bonded with Duco cement on the ⅜-inch face at the center of the critical section. After a suitable glue-bond curing period, No. 20 plastic-coated wire leads were soldered to the gages. The leads were fastened to the specimen with adhesive tape to avoid transmission of stresses to the gage by movement of the leads during handling. Finally, the entire critical section of the specimen was covered with a light-weight polyvinyl plastic film to protect the gage against mechanical damage and to reduce any tendency for the gage to adsorb or desorb moisture. By a similar technique, two specimens were prepared with compensating gages for each species. Each of these specimens had the same cross-sectional dimensions as the critical section of the test specimen, and was rigidly held in a small wooden jig. A compensating specimen and holding jig are shown in test position in Fig. 1.

All testing was carried out with a Type TT–C–L Instron Tensile Testing Instrument. Test conditions of 90 ± 1½° F and a relative vapor pressure equivalent to a nominal 12 per cent moisture content were maintained in a test chamber by means of a thermostatically controlled light bulb and a saturated sodium nitrite solution. A small centrifugal blower provided adequate air circulation in the chamber.

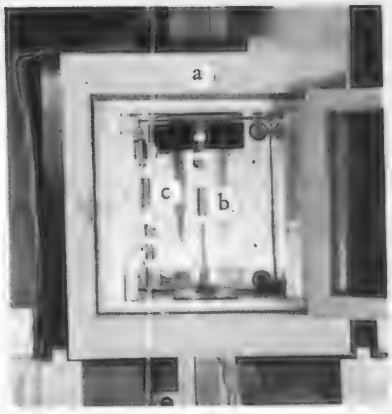

Fig. 1.—Apparatus for repetitive testing in tension parallel to the grain, showing A, test chamber; B, tension specimen; C, compensating specimen.

During a test, the specimen was positioned as shown in Fig. 1, with its central 9 inches contained within the temperature- and humidity-controlled chamber.

Initially, four specimens selected at random from each of the three series for each species were loaded to failure at a crosshead speed of 0.03 inch per minute. Strain measurements for these control specimens were made with a Baldwin Model PS–5M microformer extensometer. The results of these tests established the ultimate tensile strength and strain of each series, and permitted a selection of the various fixed stress levels to which the other specimens were loaded in a repetitive manner.

Six specimens from each of the three series were selected at random for repetitive stressing. Three specimens, one from each series, were tested at each of six stress levels: 30, 40, 50, 60, 70, and 80 per cent of the average

Table 2.—SUMMARY OF TEST DATA FOR DETERMA

Specimen number[1]	Specific gravity (O.D. Vol.)	Moisture content, (Per cent)	Assumed stress level[2]	Ultimate tensile strength (psi)	Maximum strain[3] (Micro-in./in.)	Initial strain[4] (Micro-in./in.)	Modulus of elasticity (1,000,000 psi) First cycle	Modulus of elasticity (1,000,000 psi) Last cycle	Creep (Micro-in./in.) at cycle numbers 10	20	50	100
A 1	0.48	9.0	30	12710	10000	2391	1.4499	1.4627	15	24	48	69
A 2	0.54	10.4	40	8730	7850	3624	1.2482	1.2482	88	108	136	168
A 3	0.54	8.7	50	11710	8910	4185	1.3738	1.3781	70	100	170	239
A 4	0.56	8.8	70	6940	-----	5250	1.5308	1.5386	105	170	325	557
A 5	0.59	10.5	70	12010	8260	4922	1.5810	1.5810	107	160	285	413
A 6	0.55	10.3	80	9540	8050	7329	1.5160	1.5160	343	546	---	---
Avg.	0.54	9.6	--	10270	8610	----	1.4499	1.4541				
B 1	0.56	9.8	30	12430	6790	1848	1.7317	1.7163	4	0	0	0
B 2	0.52	9.9	40	15230	7820	2682	1.6199	1.6043	24	39	66	99
B 3	0.49	9.9	50	11160	9720	3885	1.3936	1.3980	55	95	143	200
B 4	0.55	9.6	60	11480	-----	4265	1.4873	1.5304	100	145	245	345
B 5	0.55	9.6	70	10760	7510	5010	1.5252	1.5015	125	160	260	370
B 6	0.53	10.9	80	10730	7420	5498	1.5784	1.5784	128	204	357	532
Avg.	0.53	9.9	--	11960	7850	----	1.5560	1.5548				
C 1	0.55	10.3	30	15520	7630	2321	2.0938	2.1187	21	24	32	36
C 2	0.56	10.2	40	12960	7590	3500	1.8526	1.8588	34	44	88	140
C 3	0.57	10.0	50	13220	6640	3955	2.0515	2.0657	60	70	85	95
C 4	0.60	10.0	60	21290	9580	4000	2.3528	2.3528	55	85	125	165
C 5	0.59	10.5	70	17720	8500	5125	2.1895	2.1787	65	137	236	349
Avg.	0.57	10.2	--	16140	7990	----	2.1080	2.1149				
Control averages												
A series	0.56	9.0	--	11560	8900							
B series	0.52	9.7	--	10520	8120							
C series	0.56	9.8	--	16050	8940							

[1]The letters A, B, and C represent the three series of specimens.
[2]Percentage of average ultimate tensile stress of control specimens.
[3]Strain at failure after 100 stress cycles; creep strain included.
[4]Strain at the assumed stress level on the first cycle.

Table 3.—SUMMARY OF TEST DATA FOR KANEELHART

Specimen number[1]	Specific gravity (O.D. Vol.)	Moisture content, (Per cent)	Assumed stress level[2]	Ultimate tensile strength (psi)	Maximum strain[3] (Micro-in./in.)	Initial strain[4] (Micro-in./in.)	Modulus of elasticity (1,000,000 psi) First cycle	Modulus of elasticity (1,000,000 psi) Last cycle	Creep (Micro-in./in.) at cycle numbers 10	20	50	100
A 1	0.98	11.1	30	22900	-----	2250	3.6666	3.6380	0	9	18	36
A 2	1.01	11.1	40	32710	9630	3174	3.5403	3.5271	27	39	45	72
A 3	1.07	11.4	50	33280	9390	3760	3.7878	3.7648	45	63	95	145
A 4	1.00	11.2	60	27670	8040	4455	3.7916	3.6772	75	100	125	165
A 5	1.00	10.9	70	28490	8920	5635	3.4389	3.4103	90	145	275	455
A 6	1.00	10.9	80	25960	10240	6278	3.5657	3.4389	335	550	1175	2415
Avg.	1.01	11.1	--	28500	9200	----	3.6138	3.5760				
B 1	1.05	11.6	30	25950	9060	2376	4.1048	4.1048	3	6	12	15
B 2	1.04	10.5	40	26690	6070	3484	4.3954	4.3654	26	46	71	108
B 3	1.09	10.1	50	44560	10180	3329	4.7514	4.6300	28	50	88	123
B 4	1.06	11.6	60	35860	8470	4385	4.4525	4.4180	55	95	140	230
B 5	1.05	11.6	70	39860	9610	4940	4.4909	4.4454	90	145	240	370
B 6	1.05	11.6	80	30860	9060	6276	3.8302	3.3652	246	378	1026	1584
Avg.	1.06	11.2	--	33960	8740	----	4.3375	4.2665				
C 1	1.05	11.3	30	21580	5430	2814	3.9815	3.9585	30	36	45	60
C 2	1.05	10.7	40	20930	5220	3408	4.1717	------	35	46	60	93
C 3	1.09	11.2	50	31010	7210	4098	4.3259	4.3598	62	87	121	152
C 4	1.07	11.0	60	30580	7600	4570	4.2727	4.2106	90	130	188	300
C 5	1.09	11.0	70	40720	10070	5622	4.6153	4.5572	120	185	340	541
C 6	1.12	11.6	80	25290	7040	5675	4.4180	4.4640	160	230	375	610
Avg.	1.08	11.1	--	28350	7100	----	4.2975	4.3100				
Control averages												
A series	1.01	11.2	--	28000	8620							
B series	1.06	11.5	--	31550	7590							
C series	1.10	11.4	--	33630	7760							

[1]The letters A, B, and C represent the three series of specimens.
[2]Percentage of average ultimate tensile stress of control specimens.
[3]Strain at failure after 100 stress cycles; creep strain included.
[4]Strain at the assumed stress level on the first cycle.

ultimate tensile strength of the controls. A 15–20 minute gage warm-up time was allowed immediately before each test. After zero drift of the strain gage had become negligible, the testing machine was adjusted to cycle between the desired load and a load of less than 1 per cent full-scale load. The low point of the load cycle varied from 2 to 20 pounds, depending on full-scale load. Sensitivity of strain measurements ranged from ± 3 to ± 8 microinches per inch, depending on the strain magnification. In all tests, the crosshead speed was maintained at 0.03 inch per minute for both loading and unloading.

An Instron XY Recorder made possible continuous recording of the load-deformation behavior. However, due to the overlapping of contiguous cycles, a record was made of a few given cycles so that adequate spacing was maintained between the points to be measured. After 100 continuous cycles of stressing to the selected stress level had been completed, the specimen was loaded to failure at the same crosshead speed. The moisture content and specific gravity of each specimen were determined from a small sample taken adjacent to the point of failure. The slope of grain in the failure area was measured and found, for each of the three species, to range from 1:10 to 1:28+ on the tangential surfaces, while the slope of the radial surfaces was consistently less than 1:28. The average slope of grain for the three species was 1:25 for ceiba, and 1:18 for determa and kaneelhart.

Results and Analysis

Summaries of the test results are given for the three species in Tables

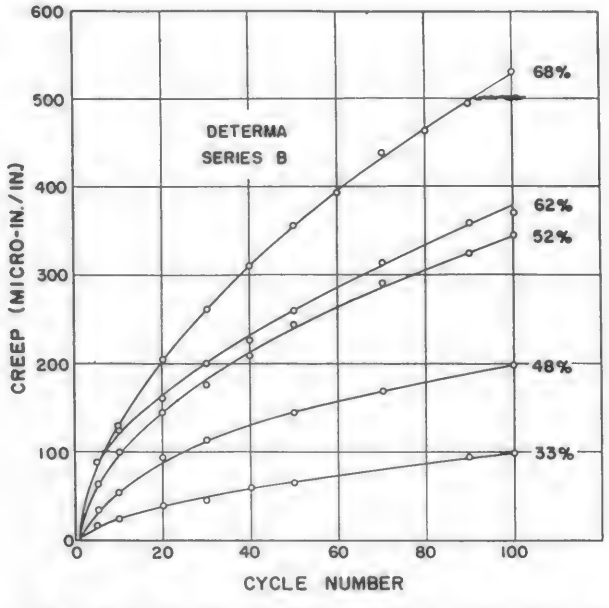

Fig. 2.—Raw test data for determa, series B. Initial strains, as percentages of the average ultimate tensile strain of the controls, are shown for the individual creep-cycle number curves.

Table 4.—EXPONENTIAL REGRESSIONS FOR THE CEIBA, DETERMA, AND KANEELHART CREEP-INITIAL STRAIN DATA

Species	Cycle Number	Exponential Regression
Ceiba	10	$\Delta\epsilon$ [1] $= e^{(3.3068 + 0.34683\,\epsilon_i)}$ [2] $_{-30}$
	20	$\Delta\epsilon = e^{(3.3369 + 0.40007\,\epsilon_i)}{}_{-30}$
	50	$\Delta\epsilon = e^{(3.6884 + 0.43014\,\epsilon_i)}{}_{-50}$
	100	$\Delta\epsilon = e^{(3.9643 + 0.45835\,\epsilon_i)}{}_{-100}$
Determa	10	$\Delta\epsilon = e^{(2.9235 + 0.39805\,\epsilon_i)}{}_{-30}$
	20	$\Delta\epsilon = e^{(3.1842 + 0.42972\,\epsilon_i)}{}_{-45}$
	50	$\Delta\epsilon = e^{(3.3160 + 0.49295\,\epsilon_i)}{}_{-55}$
	100	$\Delta\epsilon = e^{(3.4203 + 0.54295\,\epsilon_i)}{}_{-67}$
Kaneelhart	10	$\Delta\epsilon = e^{(2.7542 + 0.41755\,\epsilon_i)}{}_{-34}$
	20	$\Delta\epsilon = e^{(2.8421 + 0.46623\,\epsilon_i)}{}_{-37}$
	50	$\Delta\epsilon = e^{(2.2452 + 0.65162\,\epsilon_i)}{}_{-22}$
	100	$\Delta\epsilon = e^{(2.2033 + 0.72454\,\epsilon_i)}{}_{-21}$

[1] $\Delta\epsilon$ - Creep, microinches per inch

[2] ϵ_i - Initial strain, microinches per inch

1, 2, and 3. The maximum strain values include the increase in deformation during the cyclic loading period as well as the strain at maximum load for the last cycle. The initial strain values shown in these tables are the strains at the assumed stress level in the first loading cycle. Due to the natural variability of wood, the actual stress level expressed as a percentage of the ultimate tensile strength of each specimen varied somewhat from the assumed stress levels, which were based on the average tensile strength of the control specimens.

Although the classic definition of creep is the change in deformation under a sustained load, it is used here to describe the change in deformation at the fixed maximum load when the load is applied in a repetitive manner. Data for all three species were analyzed in the same manner. This analysis is described and illustrated in full for determa, whereas only the final results for ceiba and kaneelhart are shown. A sample of the raw data for one series of determa is shown in Fig. 2. Although the load level for each specimen was selected on the basis of percentage of ultimate tensile stress, it was found that the data exhibited minimum variability when creep was plotted against initial strain. This procedure was employed to plot creep-initial strain relationships at the 10th, 20th, 50th, and 100th stress cycles as shown in Fig. 3. Exponential regressions were fitted to each of these creep initial strain level plots by the method of least squares. These exponential regressions were of the general type:

$$\Delta\epsilon = e^{(a + b\,\epsilon_i)} - c$$

where

$\Delta\epsilon$ = creep, microinches per inch;
ϵ_i = initial strain, 1000 microinches per inch; and a, b, and c are constants.

The constant c was selected as the smallest value that would produce a linear transformation of the data. Regressions so obtained are given in Table 4. Values of initial strain at equally spaced percentages of the average ultimate tensile strain of the controls were used in these regression equations to obtain the creep-cyle number curves shown for determa in Fig. 4, and for kaneelhart and ceiba in Figs. 5 and 6, respectively. For comparative purposes, the curves for 30 and 70 per cent of ultimate tensile strain for all three species are plotted together in Fig. 7.

The effect of repetitive cycling on modulus of elasticity, ultimate tensile strain, and ultimate tensile stress was evaluated statistically. A plot of these values for determa against strain level as a percentage of the maximum strain of the controls is shown in Fig. 8. Fig 8A is a plot of the difference between the modulus of elasticity in the first and last cycle, and Figs. 8B and 8C show the ultimate stress and strain, respectively, for each specimen.

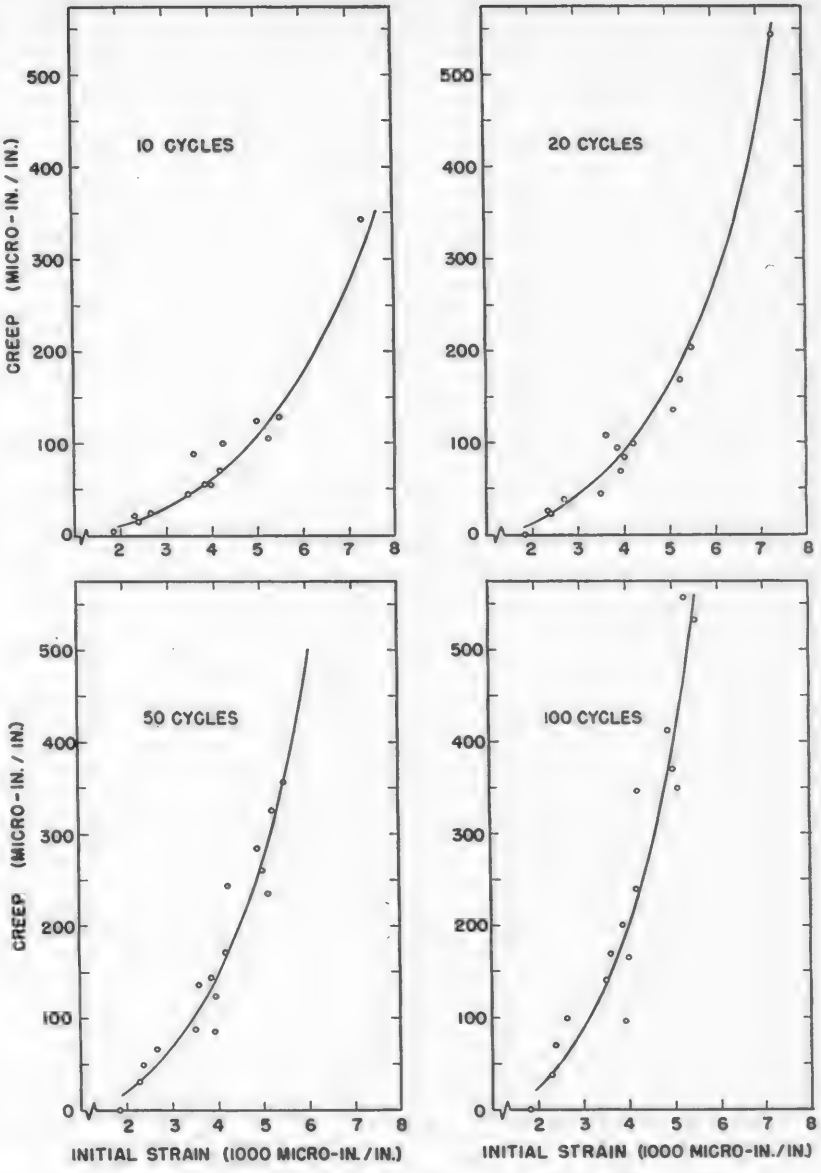

Fig. 3.—Creep-initial strain relationship for determa at 10, 20, 50, and 100 cycles.

Discussion

It may be seen in Fig. 3 that an exponential curve adequately describes the creep-initial strain relationships for determa at the four cycle levels. The equivalent curves for ceiba describe the data equally well throughout the range of 30 to 76 per cent of ultimate tensile strain. Exponential regressions for kaneelhart fit the comparable data in the range from 15 to 71 per cent of ultimate tensile strain, but the values for specimens A 6 and B 6 at 79 per cent show a marked increase in creep at all four cycle levels. Possibly this strain level exceeds some threshold of failure, and yielding is taking place at an increased rate. This change in the behavior of kaneelhart can be further illustrated by an analysis of the data showing the change in modulus of elasticity with cycling, comparable to that shown in Fig. 8A for determa. The modulus of elasticity for determa and ceiba did not change significantly during the 100 cycles in the range of strain levels tested. The same was true for kaneelhart at the low levels of strain; however, at the higher levels of strain, Young's modulus was found to be significantly decreased at the 95 per cent level of probability. This decrease in Young's modulus at high stress levels under a repeated stress is substantiated by the work of Kommers (7) in bending and compression, and

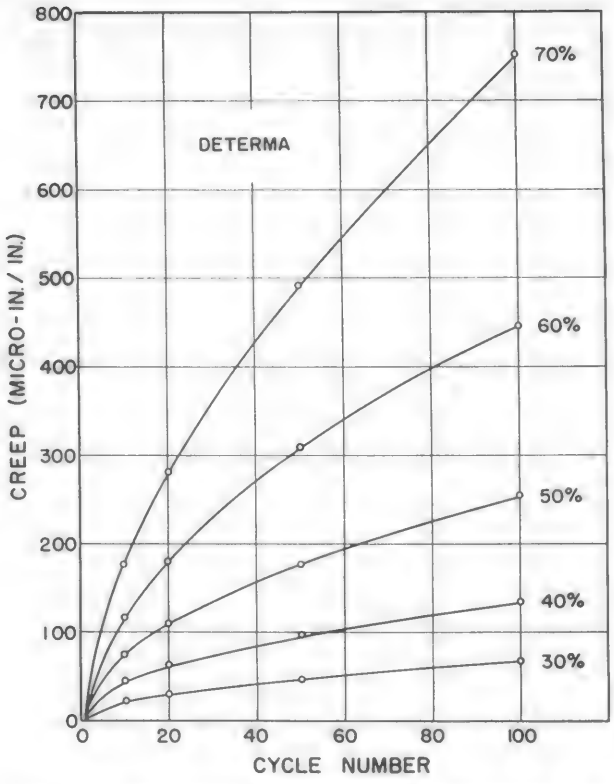

Fig. 4.—Creep response of determa for 100 repetitive stress cycles at various initial strain levels shown as percentages of the ultimate tensile strain of the controls.

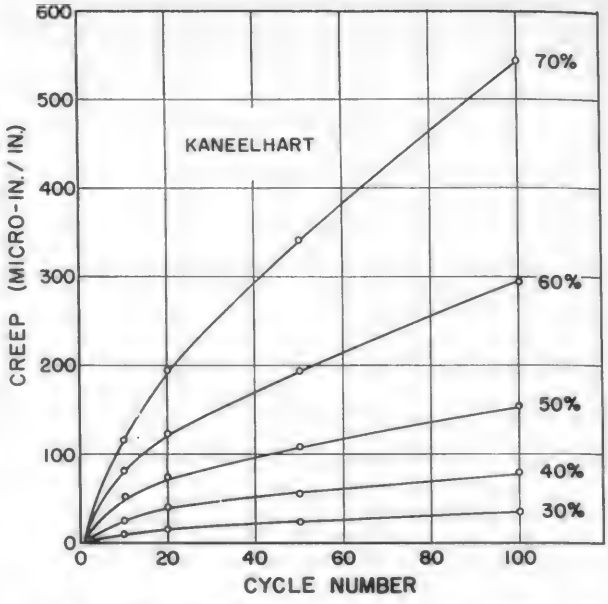

Fig. 5.—Creep response of kaneelhart for 100 repetitive stress cycles at various initial strain levels shown as percentages of the ultimate tensile strain of the controls.

by Brown, Panshin and Forsaith (3) in bending. On the other hand, Ellwood (4) reported an increase in the modulus of elasticity with cyclic loading in tension perpendicular to the grain.

The effect of 100 repetitive load cycles on ultimate tensile stress and ultimate tensile strain, as shown for determa in Figs. 8B and 8C respectively, was analyzed statistically for all three species. In each case it was found that neither of these factors differed significantly from the control values after 100 stress cycles within the range of initial strains tested.

A marked difference between the three species with regard to creep at a given percentage of their ultimate tensile strains is indicated in Fig. 7. On the basis of these species there would appear to be an inverse relationship between specific gravity and creep under repetitive stressing at a fixed percentage level. However, if the creep-cycle number relationship is plotted for fixed initial strain levels, as shown in Fig. 9, it appears that the difference between species is markedly reduced. This would seem to indicate that specific gravity has little effect on creep, even for species with values as diverse as 0.25 for ceiba and 1.05 for kaneelhart. Similarity between the curves might indicate that initial deformation is the controlling factor of

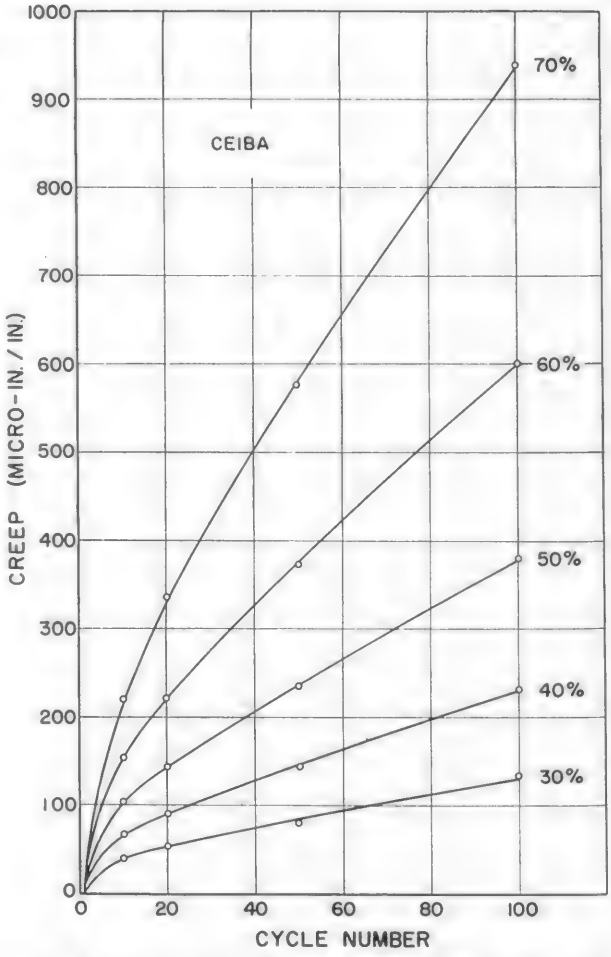

Fig. 6.—Creep response of ceiba for 100 repetitive stress cycles at various initial strain levels shown as percentages of the ultimate tensile strain of the controls.

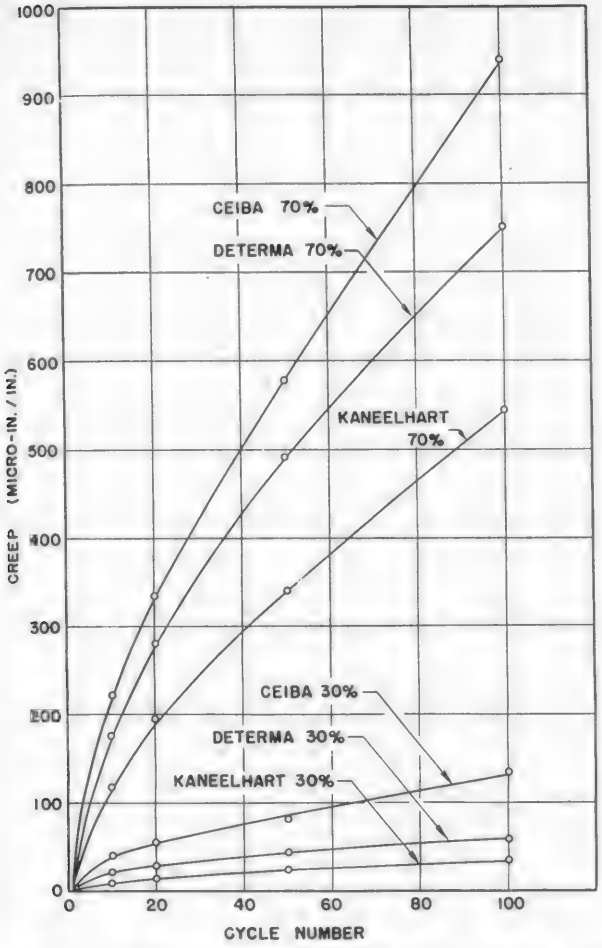

Fig. 7.—Comparison of creep curves for determa, kaneelhart, and ceiba at 30 and 70 per cent of the ultimate tensile strain of the controls.

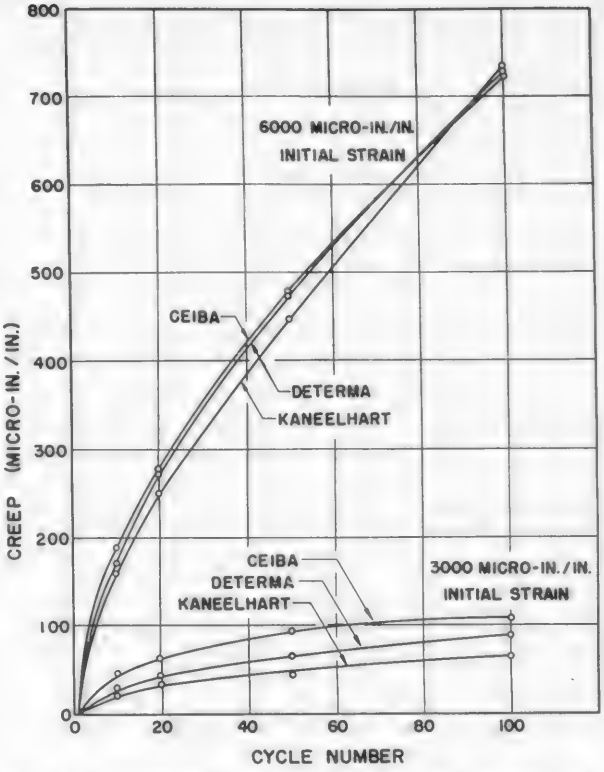

Fig. 9.—Comparison of creep curves for determa, kaneelhart, and ceiba at 3000 and 6000 microinches per inch initial strain.

creep response. It may also indicate that the cellulose network, regardless of density, will respond to a given deformation in a like manner with regard to creep under repetitive loading conditions. Before this relationship can be substantiated, it will be necessary to conduct similar tests on a greater number of species.

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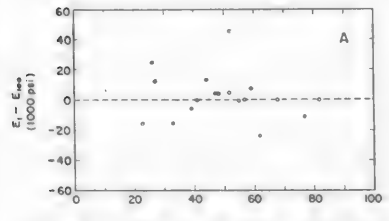

Fig. 8A.—Change in the modulus of elasticity of determa between the first and 100th cycles plotted against initial strain as a per cent of ultimate tensile strain of the controls.

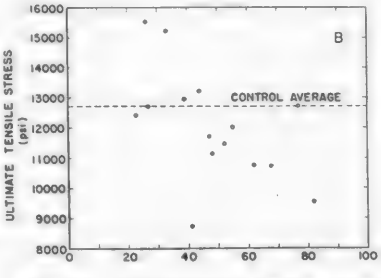

Fig. 8B.—Ultimate tensile strength of determa specimens after 100 stress cycles plotted against initial strain as a per cent of the ultimate tensile strain of the controls.

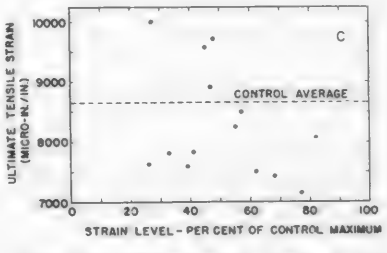

Fig. 8C.—Ultimate tensile strain of determa specimens after 100 stress cycles plotted against initial strain as a per cent of the ultimate tensile strain of the controls.

STRENGTH RETENTION IN

Wood Decayed to Small Weight Losses[1,2]

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The relationship between strength retention and weight loss was investigated for 12 woods and 2 fungi. In most cases, strength was severely reduced at a weight loss of one per cent. At equivalent weight losses, specimens attacked by the white-rotting fungus generally suffered less strength loss than those exposed to the brown-rot organism. Among the brown-rotted woods, some showed much less strength retention than others. This variation was attributed to different degrees of cellulose hydrolysis.

NATURAL DECAY RESISTANCE of woods and the efficacy of wood preservatives are most often determined in the laboratory through a series of accelerated decay tests on small wood samples. In such tests, the samples are placed in contact with pure, actively growing cultures of wood-destroying fungi. After a specific period of time has elapsed, the test blocks are removed and evaluated for degree of deterioration. The almost universally accepted system of decay evaluation is the so-called "weight-loss method," in which the dry weights of the blocks before and after exposure to fungal attack are compared. This test is very simple to perform and provides an indication of the mass of material lost in the course of decay. Often, however, strength loss due to decay is of primary importance rather than weight reduction.

This study was designed to examine the relationship between strength retention and weight loss for a number of wood species of both tropical and domestic origin.

Severe strength losses may be sustained by decayed wood that has suffered negligible losses in weight. Cartwright and others (4)[3], using a brown-rot organism to decay Sitka spruce, reported a reduction of over 25 per cent in bending strength before weight losses became apparent. They concluded that "Loss in strength would appear to be due to a chemical action on the cell wall substance rather than to a physical breaking down of the walls by hyphal penetration." In a similar investigation, Mulholland (7) used *Poria monticola,* a brown-rotting organism, to decay Sitka spruce. He noted reductions in modulus of rupture and work values in static bending before weight was significantly reduced. Richards (10) found that toughness of loblolly pine and red gum was reduced at least 50 per cent at a weight loss of only 2 per cent.

Von Pechmann and Schaile (8) observed a 20 per cent loss in toughness of Norway spruce before weight losses occurred. Similar reductions were noted in beech, even when the test pieces showed an apparent increase in weight. This work was a continuation of that begun in 1940 by Trendelenburg (11), who employed the toughness test in order to shorten the time necessary to evaluate the degree of fungal attack. He suggested that such a test would be particularly advantageous for determining the true durability of resistant tropical species that ordinarily will not show any weight loss until after 6 or 8 months of exposure under conditions ideal for the development of decay.

Of the many recognized mechanical properties of wood, toughness, or the closely allied measures of work and impact-bending strength, has proved to be the most sensitive to decay. The other mechanical properties are reduced by lesser amounts, but still to a proportionately greater degree than weight. Bending and compressive strengths are intermediate, while elasticity is the least affected by fungal penetration (2).

A great deal of variability in strength loss has been observed even at equivalent weight losses when different decay-causing fungi are involved. For example, brown-rot fungi have been shown to be twice as effective as white-rotting organisms in reducing tensile strength of beech in the incipient stage of decay (6). In southern pine decayed to a 7 per cent weight loss, Richards and Chidester (9) reported reductions in modulus of rupture of 12 and 57 per cent for *Peniophora gigantea* and *Lenzites sepiaria,* respectively. Cartwright and others (3) found that modulus of rupture decreased only 1.8 per cent in ash decayed by the white-rot fungus *Polyporus hispidus* to the extent of 1.4 per cent weight loss. At an equivalent weight loss in spruce attacked by the brown-rot organism *Trametes serialis,* modulus of rupture showed a 50 per cent decrease (4).

Richards (10) found no difference in the ability of brown and white-rotting fungi and to reduce toughness. This confirms the statement of Cartwright and Findlay (2), who summarized the difference between brown- and white-rotting organisms as follows: "Fungi causing white rots (in which all constituents of the wood are attacked) may, in the case of certain species, bring about a rapid drop in toughness, but the other strength properties are probably reduced less rapidly than by brown rots."

Another source of variability in the weight-loss method may result from the wood species used in the tests. Due to variability in chemical composition, specific gravity, and decay resistance between species, similar weight losses could conceivably be associated with different amounts of strength reduction. It was the purpose of this study to determine to what extent wood species influence strength loss associated with specific degrees of early decay. Weight loss was also measured,

[1] Second-place winner, 1958 Wood Award competition. Mr. Kennedy did this research at Yale University, and the paper was submitted through Yale.

[2] This research is part of a comprehensive study being conducted at the Yale School of Forestry in cooperation with the Office of Naval Research, Dept. of the Navy, under Contract Nonr 609(13), Project NR 330–001, Properties of Tropical Woods.

The Author: Robert Kennedy holds a BS degree from the State University of New York College of Forestry, a MF degree from the University of British Columbia, and has completed the residence requirements for the PhD at Yale.

[3] Numbers in parentheses refer to the Literature Cited at the end of this paper.

thereby permitting strength and weight losses to be correlated.

Both a brown-rot fungus *(Poria monticola*[4]*)* and a white-rot organism *(Polyporus versicolor*[5]*)* were used to further define the strength-reducing characteristics of these two classes of fungi.

Sample Preparation

Twelve wood species, representing a wide range of durability and specific gravity classes, were selected for the decay tests. Table 1 summarizes the properties of these species. For each species, two sets of samples were prepared—one for exposure to *Poria monticola* and the other to *Polyporus versicolor*. A single flat-sawn board, free from defects, was used to prepare each set of samples. The use of only one board reduced variability in strength that might otherwise be encountered because of sampling different trees or positions within a single tree. The boards were entirely heartwood, and insofar as possible exhibited straightness of grain. It was not always possible to obtain samples free from interlocked grain, but when present, it was uniform throughout the board.

Each board was planed to a thickness of 0.4 inch, and then ripped into 8 strips (numbered I through VIII) 0.25 inch thick. The radial surfaces of the strips were then planed to a final thickness of 0.20 inch. Finally, each surfaced strip was cross-cut into 8 pieces (numbered 1 through 8), thereby producing 64 samples of dimensions 0.2 by 0.4 by 4.5 inches. The samples obtained from strip VIII served to indicate the rate of decay, whereas the specimens from position 8 were used only to better establish equilibrium weights before and after decay. Their use will be discussed in the following section.

The remaining 49 pieces (strips I to VII, positions 1 to 7) were assigned letters A to G, following the design for a completely randomized 7 by 7 Latin square experiment (see Fig. 1). Each letter, appearing once in each strip and position, indicated samples that were to be subjected to decay for the same period of time. The seven pieces marked A in each species were used as the uninfected controls, whereas the pieces marked B to G were subjected to six different periods of decay, according to letter. This randomization plan mixed all test pieces homogeneously so that, theoretically, the range of natural variation in strength of a given board was represented in all beams subjected to any single period of decay.

All samples were end-coated with a room-temperature-setting resorcinol adhesive to prevent end penetration of hyphae. The 49 lettered samples and the pieces originating from position number 8 were placed in an oven at 40° C. and dried for one week to constant weight, after which they were weighed to the nearest 0.0001 gram. The samples from strip VIII were dried to a constant weight in an oven at 102° C. All specimens were then placed in test tubes and surface-sterilized by a thirty-minute exposure to steam at atmospheric pressure.

Exposure of Wood Samples to Decay

French-square bottles containing 25 ml. of Difco malt agar were employed as decay chambers. Each had been previously inoculated with either *Poria monticola* or *Polyporus versicolor*. A period of two to three weeks was allowed to elapse after inoculation, so that an actively growing mycelial mat of uniform thickness could form. One test stick, with its lettered radial side up, was inserted into each bottle. The specimens were not allowed to rest directly on the fungus mat, but were supported by sterile bent glass rods 3 mm. in diameter. Control specimens (lettered A) and those pieces from position 8 in the board were treated in the same way, with the exception that they were placed in uninoculated decay chambers. All chambers were then placed in a constant-temperature room kept at 25° C.

The pieces from strip VIII were removed at intervals from their decay chambers, oven dried once again at 102° C., and reweighed in order to provide a rapid estimate of the amount of decay that had taken place. When the wood specimens were about half-covered with mycelium, those lettered B were removed, along with one control sample and one piece from position 8 in the original board. The seven decayed samples were wiped free of excess mycelium, and then all nine

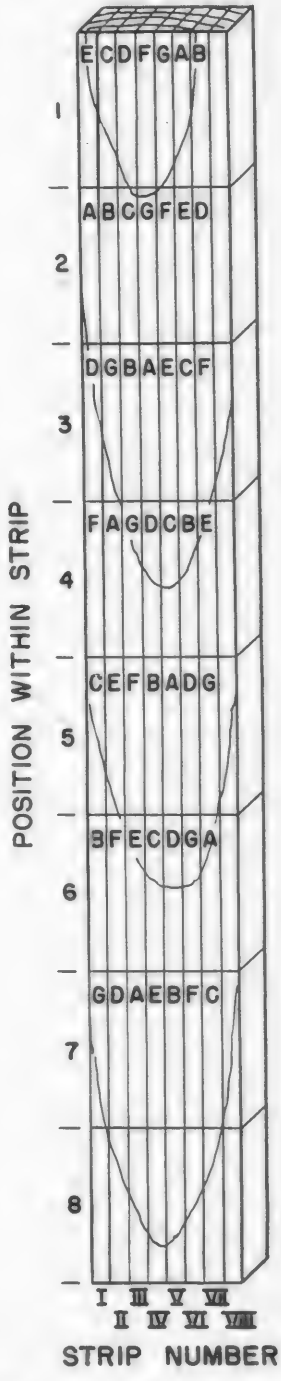

Fig. 1.—Method of sample preparation (not to scale). Samples with the same letter served as replicates for specific periods of exposure to decay.

[4] U. S. Forest Products Laboratory culture No. 698.

[5] U. S. Forest Products Laboratory culture No. 697.

Table 1.—SPECIES SELECTED FOR DECAY TESTS

Species	Specific gravity [1] (green-volume)	Durability [1]
Angelim (*Hymenolobium excelsum*)	0.63	Very durable
Angelique (*Dicorynia paraensis*)	.60	Durable
Basswood (*Tilia americana*)	.32	Non-durable
Cedro granadino (*Cedro Tonduzii*)	.41	Moderately durable
Espavé (*Anacardium excelsum*)	.42	Durable
Kaneelhart (*Licaria cayennensis*)	.96	Very durable
Larch (*Larix occidentalis*)	.48	Moderately durable
Marishiballi (*Licania buxifolia*)	.88	Very durable
Rokoroko (*Macoubea guianensis*)	.37	Non-durable
Santa Maria (*Calophyllum brasiliense*)	.52	Moderately durable
Teak (*Tectona grandis*)	.57	Very durable
White oak (*Quercus alba*)	.60	Moderately durable

[1] Data taken from Tropical Woods 98: 24–29, 1952; 99: 13–15, 1954; 103: 12–13, 1955; and Wood Handbook (Handbook No. 72, USDA) pp. 45, 70–77, 1955.

pieces were again placed in an oven at 40° C. for one week. Change in weight due to decay in the infected pieces was computed as a percentage of initial weight before decay. Initial weights were corrected to conform with subsequent changes in weight observed in the two uninfected pieces resulting from fluctuation in atmospheric humidity inside the oven.

This procedure was repeated five times with samples corresponding to letters C through G for each wood tested. An effort was made to produce weight losses greater than 2 per cent, while on the other hand, weight losses up to 12 per cent were easily reached with the nonresistant woods. Consequently, the spacing of weight losses was necessarily unequal among species, but the range of weight losses within a single species was sufficient to permit statistical analyses.

Polyporus versicolor did not develop well enough to cause decay in larch and cedro granadino, although a few pieces of each species were covered sporadically with hyphae. Therefore, these two groups were omitted from further testing. The kaneelhart specimens supported the mycelium of both wood-destroying fungi, but no significant weight losses were obtained over a six-month period. This species was tested for strength retention, but was omitted from the remaining 20 groups in which strength retention was related to weight loss.

Strength Tests

After the samples had been removed from the 40° C. oven and weighed, they were brought to an equilibrium moisture content in the range of 11 to 12 per cent, depending on the wood species. The specimens were then weighed, measured in length and cross-sectional dimensions, and tested in static bending in a Baldwin hydraulic testing machine with a load sensitivity of 0.2 pound. The samples were center-loaded on their radial face over a 3.5-inch span (span/depth ratio 17.5). The load was applied at the rate of 0.015 inch per minute through a bearing head with a radius of 0.375 inch. Specimens with odd Arabic numbers were tested so that their lettered radial face was on the compression side of the beam, while the even-numbered pieces were tested with their lettered face corresponding to the tension face of the beam. No difference in strength was noted due to testing position.

Attempts were made to measure deflection from the neutral plane, but the placing of even a very small nail at the center of the 0.2-inch-thick specimens frequently caused splitting. Instead, deflections were measured to the nearest 0.0005 inch by means of an Ames dial placed directly under the test specimen. Readings were taken at intervals of one to four pounds, depending on the species and degree of decay. Each test was continued until the load fell well below the maximum.

At the completion of the test, the pieces were oven-dried and weighed to determine the effect of decay on equilibrium moisture content. No significant differences in emc were observed, even when the control pieces were compared with the most severely decayed samples.

Only the two static bending properties most sensitive to incipient decay were computed. Modulus of rupture was determined directly from maximum load readings, and work to maximum load was calculated from the area under the load-deflection curves.

Analysis of Data

The average strength values of the seven control sticks from each board served as the basis for comparison with the decayed pieces. Weight loss and strength values were computed and averaged for the specimens subjected to each of the six individual decay periods. The average residual strength corresponding to a given decay period was expressed as a percentage of the control average. These mean values were used to plot the relationship of percentage strength retention over percentage weight loss. The resulting relationships were curvilinear, and showed a more rapid decrease in per cent strength retention in the first stages of decay than in the more advanced periods.

It seemed apparent from these approximate curves that some woods suffered greater losses in strength than others when decayed to equal weight loss by a particular fungus. The relationship of strength retention to weight loss was transformed to linear form by plotting the common logarithms of per cent strength retention against per cent weight loss. This resulted in a series of straight lines of different slopes. Thus, analysis of the data became a problem of differentiation between lines of varying slopes. The computed slopes for each combination of fungus, wood species, and strength value are listed in Table 2.

Table 2.—SLOPES OF LINES RELATING LOGARITHM OF PER CENT STRENGTH RETENTION TO PER CENT WEIGHT LOSS

Wood species	Slope for: Modulus of rupture	Slope for: Work to maximum load
Poria monticola		
Larch	—0.01415	0.01759
Rokoroko	— .03497	— .05508
Espavé	— .03765	— .05174
Marishiballi	— .03922	— .16160
Basswood	— .04021	— .05408
Cedro granadino	— .05802	— .08223
White oak	— .06759	— .11837
Angelim	— .10044	— .10374
Teak	.10467	.18626
Angelique	— .11904	— .19734
Santa Maria	— .12419	— .18426
Polyporus versicolor		
Rokoroko	—0.01882	—0.03162
Espavé	— .01886	— .03102
Marishiballi	— .06272	— .09372
Basswood	— .02515	— .04632
White oak	— .02405	— .02915
Angelim	— .04949	— .10578
Teak	— .01522	— .02433
Angelique	— .01857	— .02624
Santa Maria	— .02642	— .04986

Table 3.—VARIANCE RATIOS FOR THE SIGNIFICANCE OF SLOPES AMONG WOODS

Woods attacked by:	D.F.	F. MOR	F. Work
Polyporus versicolor	8	2.01	1.18
Poria monticola	10	22.28**	25.23**

**Significant at the 1 per cent level of probability.

Results of Decay and Strength Tests

An examination of the slopes listed in Table 2 shows that the woods infected with *Polyporus versicolor* generally had smaller negative slopes than those infected with *Poria monticola*. Smaller slopes indicate a less rapid percentage decrease in strength associated with equal percentage weight losses. Therefore, the white-rotted woods were generally reduced in relative strength at a lesser rate than were the brown-rotted species. Work values were more severely affected than modulus of rupture, as evidenced by the larger negative slopes of the former.

The slopes of the strength rentention-weight loss relationships were tested against one another by an analysis of variance. The variance ratios from these tests are shown in Table 3. The non-significant F-ratios obtained when comparing different woods attacked by *Polyporus versicolor* indicate that the slopes of the lines relating logarithm of per cent strength rentention to per cent weight loss are sufficiently similar within experimental error to be considered equal.

Therefore, average slopes embracing all of the white-rotted woods were calculated for both modulus of rupture and work to maximum load. Separate regression equations of the form

$$Y = a + bX$$

where Y = log (per cent strength retention),
a = Y intercept,
b = combined slope of all white-rotted woods,
and X = per cent weight loss

were developed for the two strength properties. By substituting values of X in these equations and determining the anti-log of Y, per cent strength retention was obtained in artithmetic units. These values were plotted

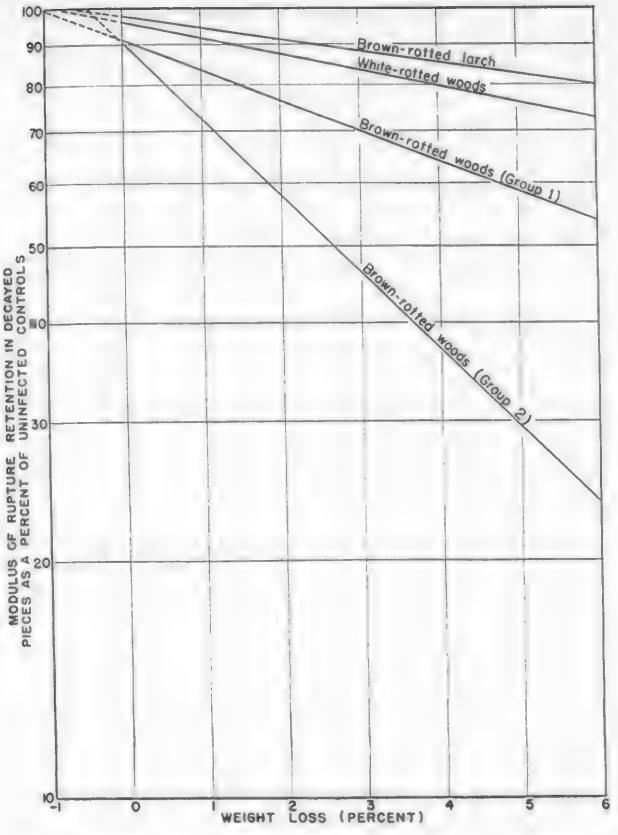
MODULUS OF RUPTURE RETENTION IN DECAYED PIECES AS A PERCENT OF UNINFECTED CONTROLS
WEIGHT LOSS (PERCENT)
Brown-rotted larch
White-rotted woods
Brown-rotted woods (Group 1)
Brown-rotted woods (Group 2)

Fig. 2.—Relationship between percentage retention of modulus of rupture and per cent weight loss. Group 1 includes rokoroko, espave, marishiballi, basswood, and cedro. Group 2 includes white oak, angelim, teak, angelique, and Santa Maria.

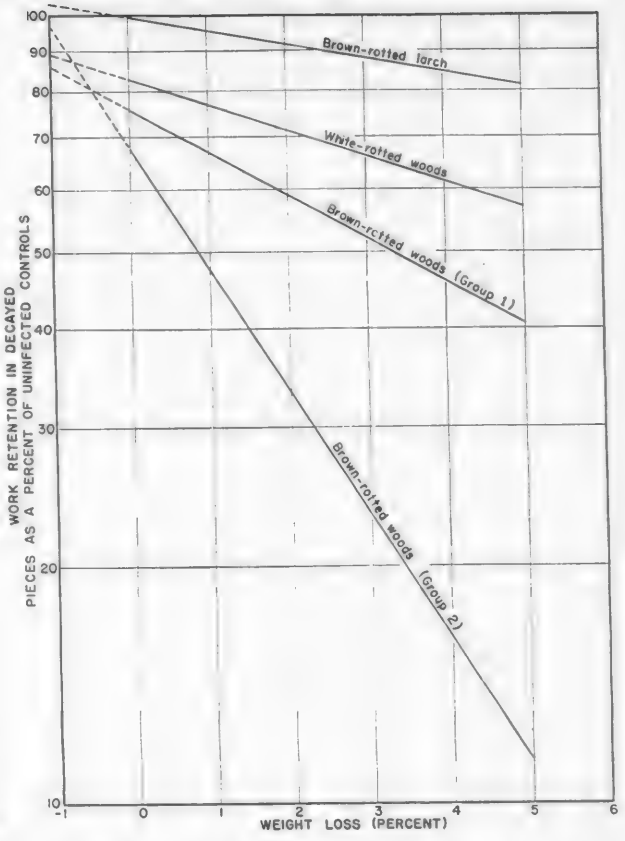
WORK RETENTION IN DECAYED PIECES AS A PERCENT OF UNINFECTED CONTROLS
WEIGHT LOSS (PERCENT)
Brown-rotted larch
White-rotted woods
Brown-rotted woods (Group 1)
Brown-rotted woods (Group 2)

Fig. 3.—Relationship between percentage retention of work to maximum load and per cent weight loss. Group 1 includes rokoroko, espave, basswood, cedro, and angelim. Group 2 includes marishiballi, white oak, teak, angelique, and Santa Maria.

against their corresponding per cent weight losses to obtain the curves shown in Figs. 2 and 3.

Replacing several lines that have insignificantly different slopes with one equation to describe them all is valid under the assumption that the individual lines have the same *Y* intercept. This hypothesis is reasonable, in view of the fact that all woods must necessarily retain 100 per cent strength before the onset of decay.

The highly significant variance ratios exhibited when the woods decayed by *Poria monticola* were compared indicate that wood species played an important role in determining the degree of strength reduction that accompanied weight loss. When the extremely low slope of larch was omitted from the analysis, the F-ratios for the differences in slope among the remaining brown-rotted woods dropped to approximately one-half of the original values. Nevertheless, the reduced variance ratios remained highly significant. Further analysis showed that the slope for larch was significantly less than that of the wood with the next lowest slope. Consequently, separate regression equations were calculated for larch. These appear graphically in Figs. 2 and 3.

Since the remaining ten brown-rotted woods still showed a significant difference in slope, further analysis was carried out in order to segregate these species into homogeneous groups. It was found that the lines relating modulus of rupture to weight loss could be divided into two groups with significantly different slopes. The first group included rokoroko, espavé, marishiballi, basswood, and cedro granadino, with slopes ranging from -0.03497 to -0.05802 (see Table 2). Including white oak, with a slope of -0.06759, in this group resulted in a significant F-ratio; therefore, Group 1 was limited to the first five species. The second group embraced white oak, angelim, teak, angelique, and Santa Maria. The variation in the slopes of the five lines representing these species was likewise non-significant. The lines representing Groups 1 and 2 are illustrated in Fig. 2.

The slopes of the remaining lines relating loss in weight to retention of work to maximum load were similarly segregated into two significantly different populations. Group 1 was made up of rokoroko, espavé, basswood, cedro granadino, and angelim. Group 2 included marishiballi, white oak, teak, angelique, and Santa Maria. The slopes within these populations were not significantly different. Lines representing these two groups are included in Fig. 3.

Although individual lines were not plotted for each wood and fungal species in Figs. 2 and 3, examination of the slopes in Table 2 indicates their variation about the combined slopes. The efficiency of the log transformation in describing linear relationships can be expressed in terms of an overall coefficient of determination. This figure indicates the proportion of the total sum of squares attributable to the linear regression, and thus provides a measure of the scatter of points about the lines. The coefficient was 0.9535 for modulus of rupture, and 0.9393 for the work-weight loss regressions. Thus, well over 90 per cent of the total variation in log of per cent strength retention was accounted for by its linear regression on per cent weight loss.

Discussion of Results

This study further demonstrates the insensitivity of weight loss as an indicator of strength reduction, and thereby confirms the work of several other investigators (4,7,8,10). Values for work to maximum load were lowered

to a greater extent than modulus of rupture before weight losses became apparent.

To determine the change in weight of the specimens when modulus of rupture was still unimpaired, it was necessary to extrapolate the lines of Fig. 2 back past zero weight loss to *negative* weight losses ranging from -0.45 to -1.00 per cent. These values are actually weight gains. Increase in weight was regularly observed in the wood samples during initial stages of decay, and was usually accompanied by loss in strength. Similar results have been reported elsewhere (7,8).

The observed gain in weight may be largely attributable to the method of testing decay resistance. In growing from the malt agar onto the wood specimens, the fungal mycelium may increase the weight of the sample due to the movement of sugars from the malt agar medium to the wood. Mulholland (7) attributed weight gain in incipiently decayed Sitka spruce to an increase in the equilibrium moisture content of the samples. In the present study, however, no significant increase in emc was observed.

Mulholland (7) has suggested that the weight-loss method of rating decay resistance in tropical species may be far too coarse, since a wood is considered "very durable" when weight losses from 0 to 10 per cent occur as a result of a 4-month period of exposure to a fungus. Evidence to support this contention can be obtained from Figs. 2 and 3, which show the severe effect that a difference in weight loss of only a few per cent can have upon strength. As an example, the results of tests upon teak and kaneelhart may be cited. Table 1 shows both of these species to be in the "very durable" category. However, a weight loss of only one per cent, as attained in teak under the attack of *Poria monticola*, carried with it concomitant reductions in modulus of rupture and work of 27 and 53 per cent, respectively. Kaneelhart specimens showed no weight losses whatsoever over a period of 6 months, and likewise displayed no reduction in either modulus of rupture or work. On this basis, kaneelhart and other species like it which show no weight losses in standard 4-month decay tests should be elevated to a superior durability classification.

A consideration of the chemical nature of decay helps to explain the different degrees of strength retention observed among the brown-rotted woods. Deterioration of wood due to brown-rotting fungi is brought about by preferential attack on the carbohydrate fraction of the wood(2). Campbell and Booth (1) concluded that this type of decay is similar to dilute-acid hydrolysis with a consequent increase in the number of short-chained carbohydrates. Since these molecules are soluble in dilute alkali, enzymatic hydrolysis brings about an increase in the solubility of decayed wood in a one per cent solution of NaOH. Cartwright and others (4) showed that alkali solubility of incipiently decayed spruce increased before weight loss occurred, indicating that some cellulose chains had been degraded. This was confirmed by noting an appreciable strength reduction in the same material.

To determine the degree of carbohydrate hydrolysis that had taken place in the woods used in this study, five brown-rotted species were chosen for alkali solubility tests. Larch was selected since it suffered the least relative modulus of rupture reduction for a given weight loss (see Fig. 2). Santa Maria was chosen because it represented the other extreme, whereas basswood, white oak, and teak typified species showing intermediate reductions in strength.

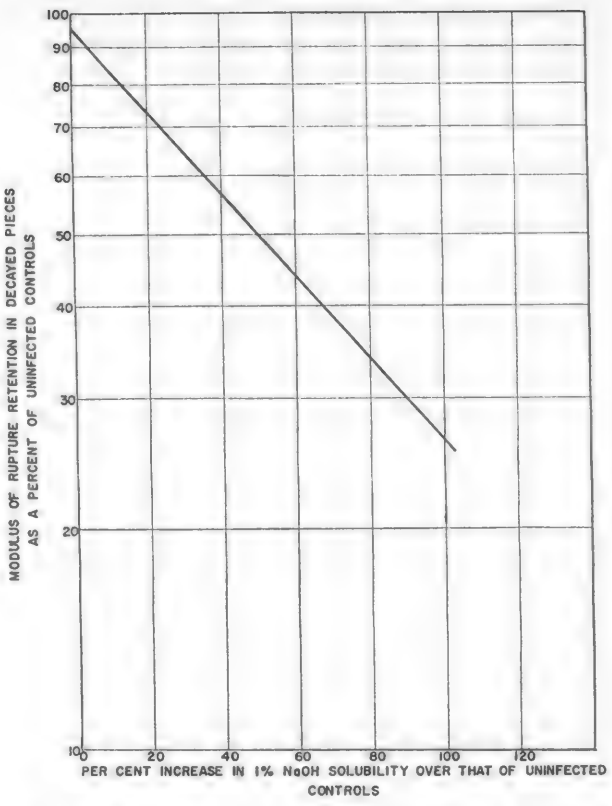

Fig. 4.—Relationship between percentage retention of modulus of rupture and increase in alkali solubility, based on species listed in Table 4.

Each set of seven samples, representing those beams of a particular species exposed to decay for the same period of time, was analyzed separately for alkali solubility. The uninfected control samples for each species were also analyzed so that alkali solubility of the decayed pieces might be expressed as a percentage increase over that of the controls. Each individual set was reduced to wood flour and analyzed in duplicate lots for solubility in one per cent sodium hydroxide. The procedure followed was that given by TAPPI Standard T 4m, as outlined by Wise and Jahn (12:1136). The amount of material soluble in the alkali solution was expressed as a percentage of the oven-dry weight of the wood flour.

In all instances, the alkali solubility of the decayed samples was greater than that of the controls. The degree to which solubility had increased in the decayed pieces was determined as follows:

$$\frac{\text{alkali solubility of decayed pieces (per cent)} - \text{alkali solubility of control pieces (per cent)}}{\text{alkali solubility of control pieces (per cent)}} \times 100 = \text{per cent increase in alkali solubility due to decay}$$

To obtain the linear relationship shown in Fig. 4, the log of the per

Table 4.—SLOPES OF LINES RELATING LOGARITHM OF PER CENT RETENTION OF MODULUS OF RUPTURE TO PER CENT INCREASE IN ALKALI SOLUBILITY

Fungus	Wood species	Slope
Poria monticola	Larch	— .006467
	Basswood	— .005446
	White oak	— .006586
	Teak	— .006896
	Santa Maria	— .005501

Table 5.—HOT-WATER SOLUBILITY OF CONTROL SAMPLES AFTER ALCOHOL-BENZENE EXTRACTION

Wood species	Hot-water solubility per cent[1]
Larch	19.20
Basswood	7.43
White oak	4.28
Teak	3.58
Santa Maria	2.51

[1]Results in percentage of oven-dry weight of alcohol-benzene extracted samples.

cent retention of modulus of rupture was plotted against per cent increase in alkali solubility. The slopes of the lines for individual species are given in Table 4. The difference between these slopes was found to be non-significant in an analysis of variance test ($F = 0.43$). Consequently, a single line representing all woods was determined by combining individual species data. The equation of this line was computed as:

$$\log Y = 1.97771 - 0.00559 X$$

where Y = per cent retention of modulus of rupture of the test pieces

and X = per cent increase in alkali solubility of the test pieces

The coefficient of determination, a measure of the goodness of fit of this regression, was calculated as 0.9555.

The similarity in slopes showed that the five woods tested suffered the same proportionate decrease in modulus of rupture for a given per cent increase in alkali solubility. This is in direct contrast to the variable degree of reduction in modulus of rupture associated with a given per cent weight loss. For example, Fig. 2 shows that, at a weight loss of 6 per cent, modulus of rupture retentions varied from 24 to 80 per cent, depending on wood species. On the other hand, Fig. 4 indicates that a specific increase in alkali solubility of 20 per cent results in a modulus of rupture retention of 74 per cent, regardless of species. It therefore appears that strength reduction is dependent on the extent to which carbohydrate hydrolysis occurs, rather than on per cent weight loss.

Those species that exhibited a low proportionate retention of modulus of rupture for a particular percentage weight loss evidently were hydrolyzed to a greater degree than woods whose strength was less seriously impaired. The differential degree of holocellulose hydrolysis that occurred among species may depend on the amount of short-chained carbohydrates originally present in wood before fungal infection. Findlay (5) has indicated that the simple carboyhydrate sugars are preferentially utilized by brown-rot fungi in the early stages of decay. He impregnated wood blocks with sucrose or dextrose and found lower weight losses of woody material in these than in untreated controls, due to the preferential utilization of the more readily available polysaccharides in the former. In the absence of these sugars, weight loss was higher due to attack on the cell-wall carbohydrates. Similarly, if the simple carbohydrates present naturally in wood are attacked first during decay, those species with large reserves of these short-chained molecules might be expected to suffer relatively little reduction in strength.

To get an indication of the short-chain carbohydrates present in the five woods investigated, hot-water solubilities of the uninfected controls were determined following TAPPI Standard T lm as outlined by Wise and Jahn (12:1134). The water-soluble determination was preceded by an alcohol-benzene extraction to remove that portion of the tannins and coloring matter that might otherwise be included with the water-soluble fraction (12:1134). The results of these tests are presented in Table 5.

The high water solubility of larch indicates that this species has a large amount of available carbohydrates. It is interesting to note in this connection that larch has an unusually large amount of a water-soluble arabo-galactan, sometimes occurring in yields of over 15 per cent (12:645). Although this material may be polymerized to a fairly high degree, the ease with which it dissolves in water could make it readily available as a nutritional source for an invading fungus.

That this material might have been preferentially utilized by the fungus is indicated by the fact that, among all species tested, larch suffered both the smallest relative strength loss and exhibited the smallest percentage increase in alkali solubility, signifying that relatively little cellulose hydrolysis had occurred. Moreover, in Table 5 it is shown that Santa Maria had the lowest water solubility. Therefore, a highly polymerized holocelulose fraction must have served as the primary source of carbohydrate for the fungus. As a result, this component may have been strongly hydrolyzed from the very outset of decay. The severe decrease in strength retention associated with small relative weight loss in this species supports this view.

Conclusions

This study was undertaken to evaluate the reliability of weight loss as an index of strength retention of small wood beams exposed to decay. Variations in percentage strength loss arose when woods were decayed to similar degrees of deterioration as measured by the weight-loss method. In this study, decay caused by the brown-rot organism *Poria monticola* generally induced higher strength losses than that caused by the white-rot fungus *Polyporus versicolor*.

No significant differences in percentage strength retention were observed among the species attacked by the white-rot fungus when compared at equivalent weight losses. On the other hand, a marked diversity in percentage of strength retention was noted among the woods when they were decomposed to equal weight losses by the brown-rot fungus. The discrepancies observed within the brown-rotted woods were eliminated when per cent retention of modulus of rupture was plotted against per cent increase in alkali solubility. Solubility of the decayed woods increased in one per cent NaOH in proportion to the severity of strength loss. This was taken to indicate that a large accumulation of low molecular weight carbohydrates accompanied high degrees of strength loss as a result of enzymatic hydrolysis of cellulose molecules.

The insensitivity of the weight-loss method as an indicator of strength reduction was demonstrated. Modulus of rupture and work to maximum load in static bending were often drastically reduced with little or no weight loss. If very durable woods are to be rated accurately in the laboratory for strength loss due to decay, the weight-loss method of evaluation should be replaced by a more sensitive test, since variations of only a few per cent in weight loss may result in quite different percentage strength losses. Furthermore, even if woods show similar low weight losses when infected with the same brown-rot fungus, their strength retentions might vary widely because of differences in cellulose degradation. As a substitute for a strength test, it is suggested that per cent increase in alkali solubility can be used to demonstrate the degree to which a brown-rotted wood has deteriorated.

Literature Cited

1. Campbell, W. G., and G. Booth. 1929. Effect of partial decay on the alkali solubility of wood. Biochem. J. 23: 566–572.

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Angelim	— .10044	— .10374
Teak	— .10467	— .18626
Angelique	— .11904	— .10724
Santa Maria	— .12419	— .184[illegible]
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Espavé	— .01886	— .0311[illegible]
Marishiballi	— .06272	— .0937
Basswood	— .02515	— .0463
White oak	— .02405	— .0291
Angelim	— .04949	— .1057
Teak	— .01522	— .024[illegible]
Angelique	— .01857	— .026
Santa Maria	— .02642	— .040[illegible]

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where Y = log (per cent strength retention),
a = Y intercept,
b = combined slope of all white-rotted woods,
and X = per cent weight loss

were developed for the two strength properties. By substituting values of X in these equations and determining the anti-log of Y, per cent strength retention was obtained in artithmetic units. These values were plotted

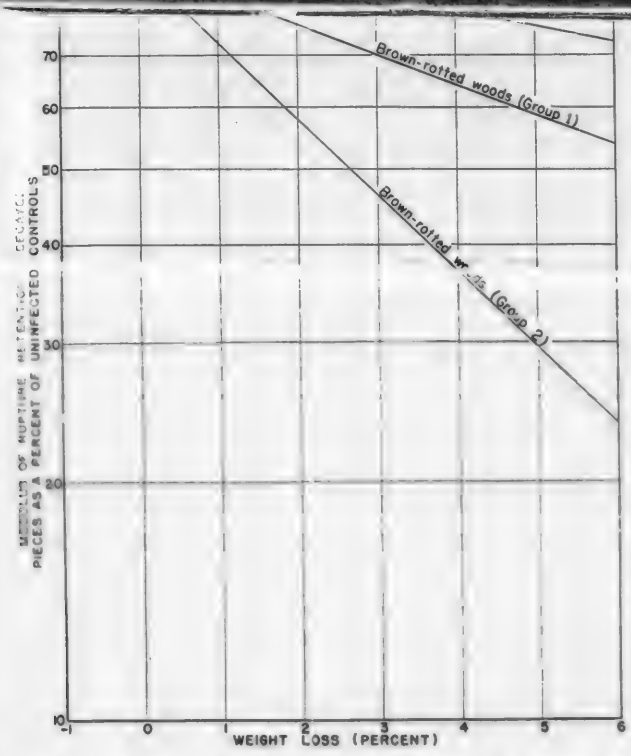

Fig. 2.—Relationship between percentage retention of modulus of rupture and per cent weight loss. Group 1 includes rokoroko, espave, marishiballi, basswood, and cedro. Group 2 includes white oak, angelim, teak, angelique, and Santa Maria.

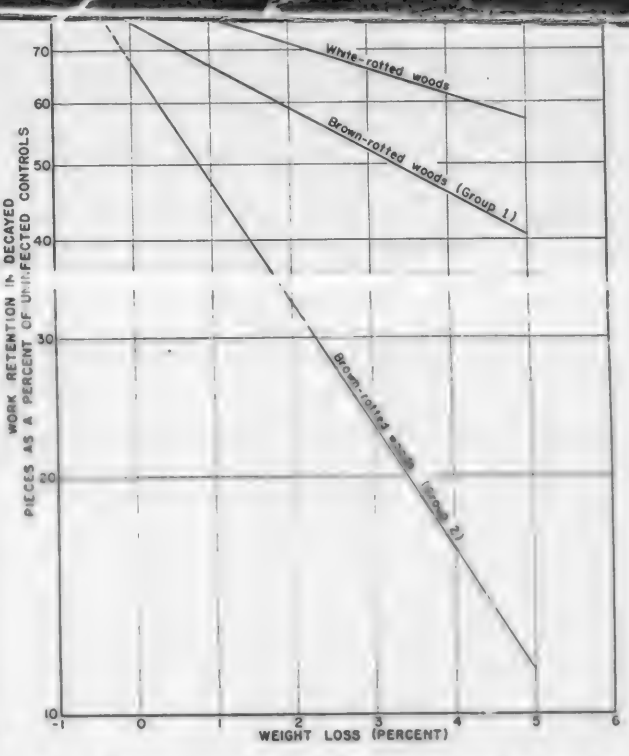
White-rotted woods
Brown-rotted woods (Group 1)
Brown-rotted woods (Group 2)
WORK RETENTION IN DECAYED PIECES AS A PERCENT OF UNINFECTED CONTROLS
WEIGHT LOSS (PERCENT)

Fig. 3.—Relationship between percentage retention of work to maximum load and per cent weight loss. Group 1 includes rokoroko, espave, basswood, cedro, and angelim. Group 2 includes marishiballi, white oak, teak, angelique, and Santa Maria.

against their corresponding per cent weight losses to obtain the curves shown in Figs. 2 and 3.

Replacing several lines that have insignificantly different slopes with one equation to describe them all is valid under the assumption that the individual lines have the same Y intercept. This hypothesis is reasonable, in view of the fact that all woods must necessarily retain 100 per cent strength before the onset of decay.

The highly significant variance ratios exhibited when the woods decayed by *Poria monticola* were compared indicate that wood species played an important role in determining the degree of strength reduction that accompanied weight loss. When the extremely low slope of larch was omitted from the analysis, the F-ratios for the differences in slope among the remaining brown-rotted woods dropped to approximately one-half of the original values. Nevertheless, the reduced variance ratios remained highly significant. Further analysis showed that the slope for larch was significantly less than that of the wood with the next lowest slope. Consequently, separate regression equations were calculated for larch. These appear graphically in Figs. 2 and 3.

Since the remaining ten brown-rotted woods still showed a significant difference in slope, further analysis was carried out in order to segregate these species into homogeneous groups. It was found that the lines relating modulus of rupture to weight loss could be divided into two groups with significantly different slopes. The first group included rokoroko, espavé, marishiballi, basswood, and cedro granadino, with slopes ranging from -0.03497 to -0.05802 (see Table 2). Including white oak, with a slope of -0.06759, in this group resulted in a significant F-ratio; therefore, Group 1 was limited to the first five species. The second group embraced white oak, angelim, teak, angelique, and Santa Maria. The variation in the slopes of the five lines representing these species was likewise non-significant. The lines representing Groups 1 and 2 are illustrated in Fig. 2.

The slopes of the remaining lines relating loss in weight to retention of work to maximum load were similarly segregated into two significantly different populations. Group 1 was made up of rokoroko, espavé, basswood, cedro granadino, and angelim. Group 2 included marishiballi, white oak, teak, angelique, and Santa Maria. The slopes within these populations were not significantly different. Lines representing these two groups are included in Fig. 3.

Although individual lines were not plotted for each wood and fungal species in Figs. 2 and 3, examination of the slopes in Table 2 indicates their variation about the combined slopes. The efficiency of the log transformation in describing linear relationships can be expressed in terms of an overall coefficient of determination. This figure indicates the proportion of the total sum of squares attributable to the linear regression, and thus provides a measure of the scatter of points about the lines. The coefficient was 0.9535 for modulus of rupture, and 0.9393 for the work-weight loss regressions. Thus, well over 90 per cent of the total variation in log of per cent strength retention was accounted for by its linear regression on per cent weight loss.

Discussion of Results

This study further demonstrates the insensitivity of weight loss as an indicator of strength reduction, and thereby confirms the work of several other investigators (4,7,8,10). Values for work to maximum load were lowered

to a greater extent than modulus of rupture before weight losses became apparent.

To determine the change in weight of the specimens when modulus of rupture was still unimpaired, it was necessary to extrapolate the lines of Fig. 2 back past zero weight loss to *negative* weight losses ranging from -0.45 to -1.00 per cent. These values are actually weight gains. Increase in weight was regularly observed in the wood samples during initial stages of decay, and was usually accompanied by loss in strength. Similar results have been reported elsewhere (7,8).

The observed gain in weight may be largely attributable to the method of testing decay resistance. In growing from the malt agar onto the wood specimens, the fungal mycelium may increase the weight of the sample due to the movement of sugars from the malt agar medium to the wood. Mulholland (7) attributed weight gain in incipiently decayed Sitka spruce to an increase in the equilibrium moisture content of the samples. In the present study, however, no significant increase in emc was observed.

Mulholland (7) has suggested that the weight-loss method of rating decay resistance in tropical species may be far too coarse, since a wood is considered "very durable" when weight losses from 0 to 10 per cent occur as a result of a 4-month period of exposure to a fungus. Evidence to support this contention can be obtained from Figs. 2 and 3, which show the severe effect that a difference in weight loss of only a few per cent can have upon strength. As an example, the results of tests upon teak and kaneelhart may be cited. Table 1 shows both of these species to be in the "very durable" category. However, a weight loss of only one per cent, as attained in teak under the attack of *Poria monticola,* carried with it concomitant reductions in modulus of rupture and work of 27 and 53 per cent, respectively. Kaneelhart specimens showed no weight losses whatsoever over a period of 6 months, and likewise displayed no reduction in either modulus of rupture or work. On this basis, kaneelhart and other species like it which show no weight losses in standard 4-month decay tests should be elevated to a superior durability classification.

A consideration of the chemical nature of decay helps to explain the different degrees of strength retention observed among the brown-rotted woods. Deterioration of wood due to brown-rotting fungi is brought about by preferential attack on the carbohydrate fraction of the wood(2). Campbell and Booth (1) concluded that this type of decay is similar to dilute-acid hydrolysis with a consequent increase in the number of short-chained carbohydrates. Since these molecules are soluble in dilute alkali, enzymatic hydrolysis brings about an increase in the solubility of decayed wood in a one per cent solution of NaOH. Cartwright and others (4) showed that alkali solubility of incipiently decayed spruce increased before weight loss occurred, indicating that some cellulose chains had been degraded. This was confirmed by noting an appreciable strength reduction in the same material.

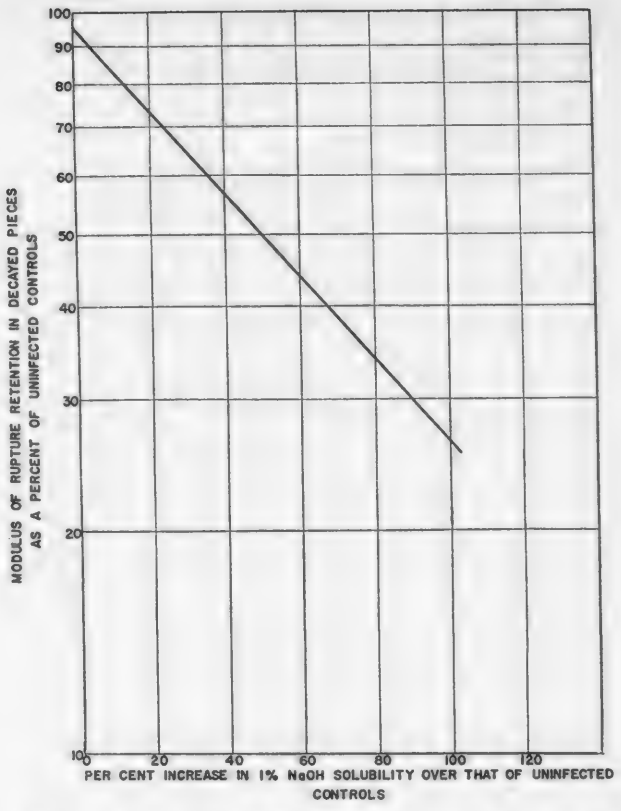

Fig. 4.—Relationship between percentage retention of modulus of rupture and increase in alkali solubility, based on species listed in Table 4.

To determine the degree of carbohydrate hydrolysis that had taken place in the woods used in this study, five brown-rotted species were chosen for alkali solubility tests. Larch was selected since it suffered the least relative modulus of rupture reduction for a given weight loss (see Fig. 2). Santa Maria was chosen because it represented the other extreme, whereas basswood, white oak, and teak typified species showing intermediate reductions in strength.

Each set of seven samples, representing those beams of a particular species exposed to decay for the same period of time, was analyzed separately for alkali solubility. The uninfected control samples for each species were also analyzed so that alkali solubility of the decayed pieces might be expressed as a percentage increase over that of the controls. Each individual set was reduced to wood flour and analyzed in duplicate lots for solubility in one per cent sodium hydroxide. The procedure followed was that given by TAPPI Standard T 4m, as outlined by Wise and Jahn (12:1136). The amount of material soluble in the alkali solution was expressed as a percentage of the oven-dry weight of the wood flour.

In all instances, the alkali solubility of the decayed samples was greater than that of the controls. The degree to which solubility had increased in the decayed pieces was determined as follows:

$$\frac{\text{alkali solubility of decayed pieces (per cent)} - \text{alkali solubility of control pieces (per cent)}}{\text{alkali solubility of control pieces (per cent)}} \times 100 = \text{per cent increase in alkali solubility due to decay}$$

To obtain the linear relationship shown in Fig. 4, the log of the per

Table 4.—SLOPES OF LINES RELATING LOGARITHM OF PER CENT RETENTION OF MODULUS OF RUPTURE TO PER CENT INCREASE IN ALKALI SOLUBILITY

Fungus	Wood species	Slope
oria monticola	Larch	— .006467
	Basswood	— .005446
	White oak	— .006586
	Teak	— .006896
	Santa Maria	— .005501

Table 5.—HOT-WATER SOLUBILITY OF CONTROL SAMPLES AFTER ALCOHOL-BENZENE EXTRACTION

Wood species	Hot-water solubility per cent[1]
Larch	19.20
Basswood	7.43
White oak	4.28
Teak	3.58
Santa Maria	2.51

[1]Results in percentage of oven-dry weight of alcohol–benzene extracted samples.

cent retention of modulus of rupture was plotted against per cent increase in alkali solubility. The slopes of the lines for individual species are given in Table 4. The difference between these slopes was found to be non-significant in an analysis of variance test ($F = 0.43$). Consequently, a single line representing all woods was determined by combining individual species data. The equation of this line was computed as:

$$\log Y = 1.97771 - 0.00559 X$$

where Y = per cent retention of modulus of rupture of the test pieces

and X = per cent increase in alkali solubility of the test pieces

The coefficient of determination, a measure of the goodness of fit of this regression, was calculated as 0.9555.

The similarity in slopes showed that the five woods tested suffered the same proportionate decrease in modulus of rupture for a given per cent increase in alkali solubility. This is in direct contrast to the variable degree of reduction in modulus of rupture associated with a given per cent weight loss. For example, Fig. 2 shows that, at a weight loss of 6 per cent, modulus of rupture retentions varied from 24 to 80 per cent, depending on wood species. On the other hand, Fig. 4 indicates that a specific increase in alkali solubility of 20 per cent results in a modulus of rupture retention of 74 per cent, regardless of species. It therefore appears that strength reduction is dependent on the extent to which carbohydrate hydrolysis occurs, rather than on per cent weight loss.

Those species that exhibited a low proportionate retention of modulus of rupture for a particular percentage weight loss evidently were hydrolyzed to a greater degree than woods whose strength was less seriously impaired. The differential degree of holocellulose hydrolysis that occurred among species may depend on the amount of short-chained carbohydrates originally present in wood before fungal infection. Findlay (5) has indicated that the simple carboyhydrate sugars are preferentially utilized by brown-rot fungi in the early stages of decay. He impregnated wood blocks with sucrose or dextrose and found lower weight losses of woody material in these than in untreated controls, due to the preferential utilization of the more readily available polysaccharides in the former. In the absence of these sugars, weight loss was higher due to attack on the cell-wall carbohydrates. Similarly, if the simple carbohydrates present naturally in wood are attacked first during decay, those species with large reserves of these short-chained molecules might be expected to suffer relatively little reduction in strength.

To get an indication of the short-chain carbohydrates present in the five woods investigated, hot-water solubilities of the uninfected controls were determined following TAPPI Standard T lm as outlined by Wise and Jahn (12:1134). The water-soluble determination was preceded by an alcohol-benzene extraction to remove that portion of the tannins and coloring matter that might otherwise be included with the water-soluble fraction (12:1134). The results of these tests are presented in Table 5.

The high water solubility of larch indicates that this species has a large amount of available carbohydrates. It is interesting to note in this connection that larch has an unusually large amount of a water-soluble arabo-galactan, sometimes occurring in yields of over 15 per cent (12:645). Although this material may be polymerized to a fairly high degree, the ease with which it dissolves in water could make it readily available as a nutritional source for an invading fungus.

That this material might have been preferentially utilized by the fungus is indicated by the fact that, among all species tested, larch suffered both the smallest relative strength loss and exhibited the smallest percentage increase in alkali solubility, signifying that relatively little cellulose hydrolysis had occurred. Moreover, in Table 5 it is shown that Santa Maria had the lowest water solubility. Therefore, a highly polymerized holocelulose fraction must have served as the primary source of carbohydrate for the fungus. As a result, this component may have been strongly hydrolyzed from the very outset of decay. The severe decrease in strength retention associated with small relative weight loss in this species supports this view.

Conclusions

This study was undertaken to evaluate the reliability of weight loss as an index of strength retention of small wood beams exposed to decay. Variations in percentage strength loss arose when woods were decayed to similar degrees of deterioration as measured by the weight-loss method. In this study, decay caused by the brown-rot organism *Poria monticola* generally induced higher strength losses than that caused by the white-rot fungus *Polyporus versicolor.*

No significant differences in percentage strength retention were observed among the species attacked by the white-rot fungus when compared at equivalent weight losses. On the other hand, a marked diversity in percentage of strength retention was noted among the woods when they were decomposed to equal weight losses by the brown-rot fungus. The discrepancies observed within the brown-rotted woods were eliminated when per cent retention of modulus of rupture was plotted against per cent increase in alkali solubility. Solubility of the decayed woods increased in one per cent NaOH in proportion to the severity of strength loss. This was taken to indicate that a large accumulation of low molecular weight carbohydrates accompanied high degrees of strength loss as a result of enzymatic hydrolysis of cellulose molecules.

The insensitivity of the weight-loss method as an indicator of strength reduction was demonstrated. Modulus of rupture and work to maximum load in static bending were often drastically reduced with little or no weight loss. If very durable woods are to be rated accurately in the laboratory for strength loss due to decay, the weight-loss method of evaluation should be replaced by a more sensitive test, since variations of only a few per cent in weight loss may result in quite different percentage strength losses. Furthermore, even if woods show similar low weight losses when infected with the same brown-rot fungus, their strength retentions might vary widely because of differences in cellulose degradation. As a substitute for a strength test, it is suggested that per cent increase in alkali solubility can be used to demonstrate the degree to which a brown-rotted wood has deteriorated.

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Improved Device for Measuring Deformation

OF WOOD SPECIMENS IN COMPRESSION PARALLEL TO THE GRAIN[1]

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Standard compressometers depend on uniform surface motion of the specimen at the point of attachment to the instrument. Since wood is non-homogeneous, it may become distorted under stress. This new device, based on a universal-joint principle, gives more accurate, dependable results.

THE AMERICAN SOCIETY FOR TESTING MATERIALS Specification D 143–52 requires that deformations of small, clear timber specimens tested in compression parallel to the grain be measured to 0.0001 inch. Several types of compressometers have been devised to make such measurements, each with its own individual characteristics and merits. It would appear, however, that all have one characteristic in common in that accuracy is dependent on uniform surface motion in the vertical direction at the points of attachment of the instrument to the specimen.

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J. T. Yelf is a graduate of the Vancouver Technical School. He has been with the Vancouver Laboratory since 1944, and has participated in the design and fabrication of numerous items of laboratory equipment.

Modification Eliminates Effects of Non-Homogeneity

Since wood is non-homogeneous, the strain developed with application of load is non-uniform, and initially plane cross sections of the specimen tend to distort and rotate. If cross sections at points of attachment of the compressometer remain normal to the axis of the specimen throughout the test, or if rotation of these cross sections is about the points of attachment, accuracy is maintained; however, rotation of the cross sections in any other direction induces slippage at the points of attachment and results in erroneous readings. To overcome this disadvantage, a modification was made to one particular type of instrument to enable it to function accurately irrespective of strain irregularity or buckling action of the specimen. To properly incorporate the modification, a similar instrument of larger dimensions than the original had to be constructed.

Fig. 1.—Improved compressometer attached to a specimen.

Working drawings are shown on Figs. 2, 3, and 4.

[1] A contributed paper (received March, 1958) from the Forest Products Laboratories of Canada, a Division of the Forestry Branch, Department of Northern Affairs and National Resources.

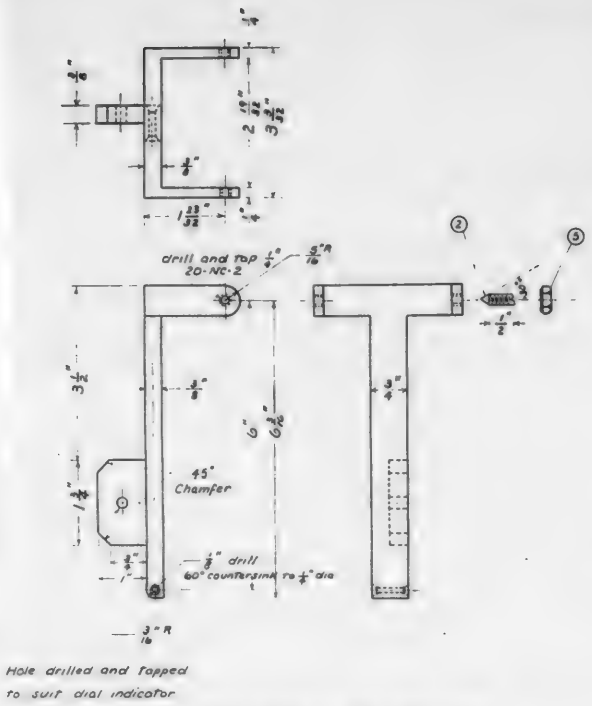

Fig. 2.—Working drawing of the main frame.

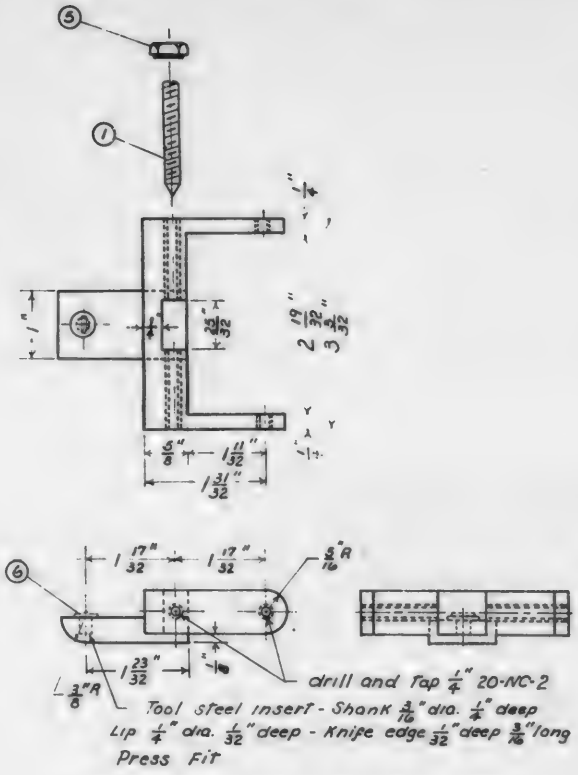

Fig. 3.—Working drawing of the base equalizer.

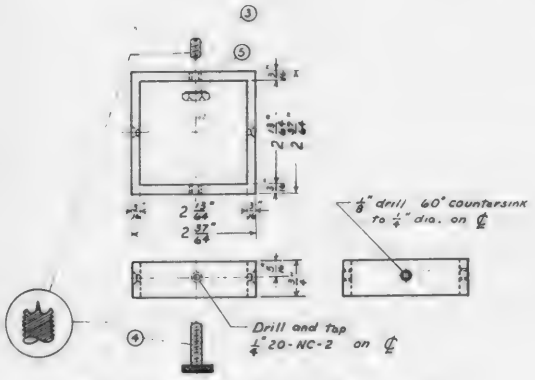

Fig. 4.—Working drawing of the collars.

Table 1.—BILL OF MATERIALS

No.	Name	Material	Size	Req'd
	Main frame	Std. brass stock		1
	Base equalizer	Std. brass stock		1
	Collars	Std. brass stock		2
	Mounting jig	Std. brass stock		1
1	60° Pt. set screw	Steel	1/4" 20-NC-2 1 3/8" L	2
2	60° Pt. set screw	Steel	1/4" 20-NC-2 1/2" L	4
3	Special Pt. set screw	Steel	1/4" 20-NC-2 5/8" L	2
4	Thumb screw (knurled head)	Steel	1/4" 20-NC-2 1" L	2
5	Nuts 3/32" thick	Steel	1/4" 20-NC-2	8
6	Knife edge	Tool steel		1

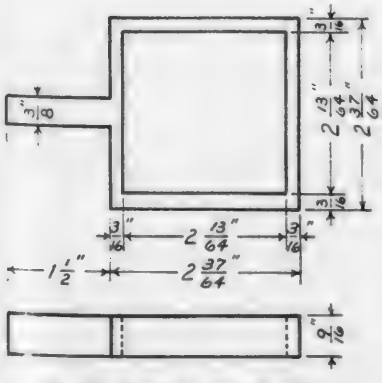

Fig. 5.—Working drawing of the mounting jig.

Description

The modification consists of two collars (Fig. 4) spaced 6 inches apart, one of which is mounted on pivots to the main frame (Fig. 2), the other on pivots to the base equalizer (Fig. 3). A dial micrometer is so secured that motion of the base equalizer in relation to the upper collar is indicated. The test specimen is held on two opposite faces by special pivot points (see detail, Fig. 4), which are in the same plane but at right angles to those in the main frame. A special jig that greatly assists in mounting the specimen to the

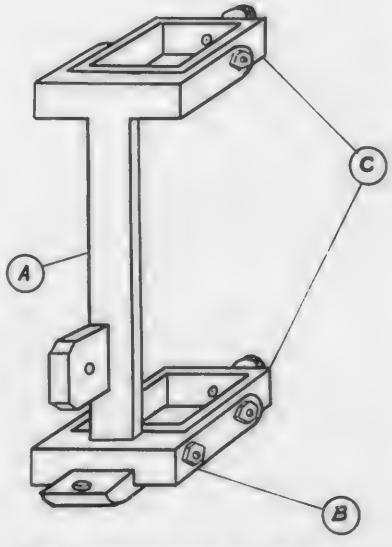

Fig. 6.—Isometric view of the assembly.

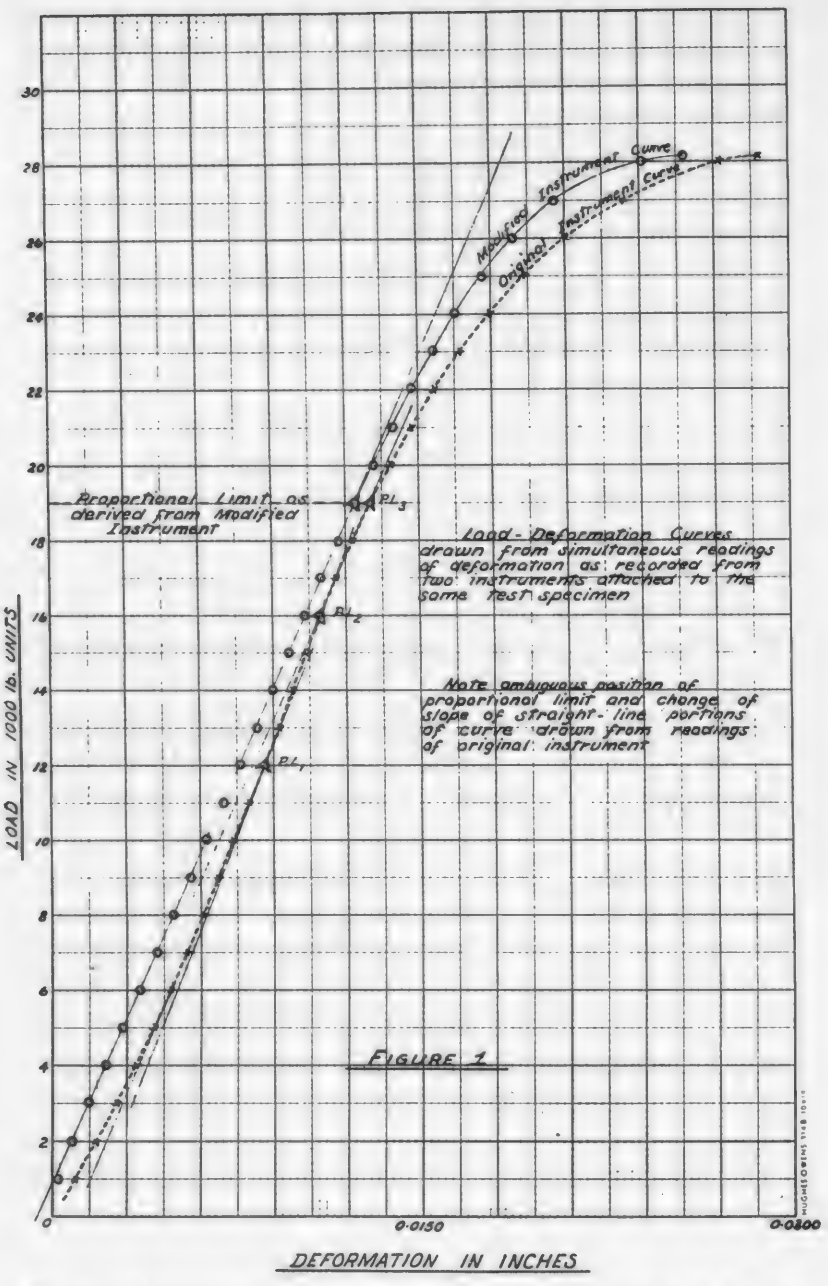

FIGURE 1

Fig. 7.—Load-deformation curves for the two instruments. The solid line is the improved device, while the dotted line is the original instrument.

instrument is shown in Fig. 5. Fig. 5 is an isometric view of the assembly. Fig. 1 shows the instrument mounted on a specimen.

Discussion

A standard test specimen for compression parallel to the grain measures 2 inches by 2 inches by 8 inches. The axial deformation within a central 6-inch gage length of this prism is the required measurement. Where non-uniform strain is present, it is desirable that the average strain with each increment of load be recorded.

Among the various strain-recording instruments, the optical-lever type appears to be one of the most accurate, but the setting-up of the apparatus is time consuming and lacks the simplicity of other types. Consideration of other methods of deformation measurement suggested that a modified version of an instrument employing a lever principle, where deformation of the test specimen actuates the lever and a dial micrometer, would effect a definite improvement in strain recording. The original instrument had the inherent advantage of simplicity and speed of application. It was, however, subject to the aforementioned fallacies under certain conditions of non-uniform strain. Load-deformation curves plotted from readings of the original instrument where such conditions exist show irregularity and ambiguity in respect to the position of the proportional limit. The dotted curve shown in Fig. 7 illustrates this undesirable feature. In order that this instrument record average strain within the gage length of the test specimen regardless of strain irregularity, a universal-joint principle was embodied in the form of the two collars mentioned previously.

A comparison of the two instruments was made by attaching them both to the same test specimen. To accommodate both instruments, test specimens were made 2 inches longer than the standard 8-inch length. Ten tests were made in this manner, and the results were averaged to produce the curves shown in Fig. 7. It may be noted that the proportional limit of the curve produced by the modified instrument is well defined and that deformation is proportional to the load at points below the proportional limit. On the other hand, the curve plotted from readings of the original instrument is somewhat 's' shaped and some doubt exists as to the actual position of the proportional limit. The slope of straight-line portions from which the modulus of elasticity is derived is also ambiguous. This characteristic was evident to a varying degree in tests on Douglas-fir, western white spruce, and black cottonwood, and was particularly predominant in tests on air-dried western white birch. Seventy-one per cent of 45 tests of white birch showed this tendency. As it was evident that the 's' shaped graph was not the normal curve, some research was undertaken with the objective of improving existing methods of deformation measurement.

The results of 258 subsequent tests showed a very definite refinement in precision and reliability.

Conclusions

The universal-joint principle allows this described instrument to function freely: plane cross sections of the specimen can rotate without binding or tearing at the points of attachment of the instrument to the specimen. This feature increases the dependability and accuracy of the test results. The over-all effect of the universal joint is to average the varying deformations within the gage length.

Ease and speed of application, simplicity and directness of reading, and the advantage of one-man observation of the instrument are retained in the modified compressometer.

EFFECT OF PARTICLE GEOMETRY AND RESIN CONTENT ON Bending Strength of Oak Flake Board[1]

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A series of boards was made in a range of resin content, flake length, and flake thickness. Resin was added on the basis of surface area. Results of boards tested in bending were analyzed on the basis of a modulus of rupture. Bending strength increased with increase in flake length up to 4 inches. Effect of resin content was secondary to flake geometry. Increased flake thickness decreased strength markedly, although this may be partially due to differences in flake surface quality. Strength increases with the length-to-thickness ratio up to 300.

PARTICLE-BOARD PLANT CAPACITY in this country has increased from an annual production of approximately 30 million square feet of ¾-inch board in 1956 until by mid-1958 the rate of production will approach half a billion square feet per year.[3]

In spite of this tremendous industry growth, relatively little is known concerning the combinations of raw material and process variables that will produce most economically a board engineered for a given use. Theoretically at least, the manufacturer of particle board has at his disposal a large number of raw material, particle, binder, mat formation, and pressing variables by which he can control the properties of his product.

Cut and try methods may yield a satisfactory combination of those variables most easily controlled in a particular manufacturing situation. However, the most efficient combination of these variables is likely to result only when board properties are known over a wide range of each. It is toward this end and to serve as a guide in future work that this study was undertaken. Specifically, the objective was to determine the effects of particle geometry and resin content upon such properties as bending strength, screw withdrawal, internal bond, and dimensional stability. This paper will discuss the effects of these variables upon bending strength only.

Fig. 2.—Author cuts ribbons from pulp bolts on a metal-working lathe.

Procedure

Experimental Design: Limitations of facilities available for manufacturing flakes and pressing board placed some restrictions upon the design of this experiment. Of the three dimensions of the flakes, only the length and thickness could be reasonably well controlled by the method available for their production. Average flake width could be measured but not controlled. To cover as wide a range of sizes as possible and still concentrate the data in regions of most interest, both flake length and flake thickness were varied in geometric progression. Turner[4], in working with sitka spruce, found that at 4 per cent phenolic resin the optimum thickness occurred at about 0.018 inch. Flake thicknesses of 0.006, 0.012, 0.025, and 0.050 inch were selected to give data on both sides of this point. Flake lengths were chosen at 0.5, 1, 2, and 4 inches. A rule of thumb commonly accepted in Europe is that length should be 120 times thickness. The various combinations of length and thickness possible here give a range of length to thickness ratios of from 10 to 667, also in approxi-

[4] Turner, H. D. 1954. Effect of particle size and shape on strength and dimensional stability of resin-bonded wood particle panels. Forest Prod. J., 4:210–223.

FLAKE LENGTH INCHES	RESIN SPREAD											
	3.27 G/M²				6.54 G/M²				13.07 G/M²			
	FLAKE THICKNESS—INCHES											
	.006	.012	.025	.050	.006	.012	.025	.050	.006	.012	.025	.050
.5												
1												
2												
4												

Fig. 1.—Experimental design.

[1] Honorable Mention, 1958 Wood Award competition. Authorized for publication September, 1958, in the Journal Series of the Pennsylvania Agricultural Experiment Station as paper number 2289.

[2] This work was supported through a grant of the Pennsylvania Dept. of Forests and Waters.

[3] Anon. 1958. Particle board: 1958. Indus. Woodworking, 10:4.

The Author: Paul Post holds a BS from Penn. State University, and has specialized his graduate work in particle board. He has been employed as an instructor in the School of Forestry, and has done summer work with the U. S. Forest Service and the Simpson Logging Co.

mately a geometric progression, making it possible to check the validity of this rule.

In nearly all research work to date and in commercial practice, resin solids have been added as a given per cent of the weight of the particles. Because of the tremendous range of surface areas for a given weight of particles which occurs with the particle sizes used here, this method was not deemed satisfactory for this study. It was decided, therefore, to apply resin to the particles on the basis of their surface area rather than by weight. A formula for determining the surface area of rectangular particles was developed as follows:

Consider a particle of width *W*, length *L*, and thickness *T*. If smooth plane surfaces are assumed, its surface area, *a*, will be

$$a = 2(TL + WL + TW)$$

Its weight, *w*, will be

$$w = WTL \times \frac{\text{Weight}}{\text{Unit Volume}}$$

The surface area, *A*, per unit weight of particles will be

$$A = \frac{a}{w} = \frac{2\ (TL + WL + TW)}{WTL \times \text{Wt/unit volume of material}}$$

If all dimensions are in centimeters and weight is in grams, weight per unit volume of material is equal to its specific gravity, *S.G.*, and

$$A = \frac{2}{S.G.}\left[\frac{TL + WL + TW}{WTL}\right]$$

For this study, particle width could not be closely controlled. Particle length, although well controlled, does not have a great influence upon surface area. For purposes of this study, therefore, particle length and width were arbitrarily fixed at one inch to give the formula:

$$A = \frac{2}{S.G.}\left[\frac{1}{T} + 2\right] \cdot K$$

Where *K* is a constant to convert linear measurements in inches to centimeters. Here *K* was further modified to give *A* in M^2/Kg when *L*, *T* and *W* are in inches. On the basis of the published value for the specific gravity of scarlet oak of 0.71, surface areas per kilogram of flakes were computed according to the formula:

$$A = \left[\frac{2}{T} + 4\right] 0.05545\ M^2/Kg.$$

The assumption of smooth, plane flake surfaces is obviously an oversimplification. Surface roughness might easily as much as double the areas given by this equation. In the absence of a method for evaluating this factor, however, its effect upon surface area will not be considered.

The resin spread corresponding to Turner's 1 × 3 × .018 inch flakes at 4 per cent resin is about 3.27 grams per square meter of surface area. It was originally intended to use this value as the middle point, with one half and double this amount as points on either side. However, considerable resin losses during spraying were thought to occur, and it was decided to double all amounts to give three resin spreads of 3.27, 6.54 and 13.07 grams of resin solids per square meter. For convenience of application, the per cent resin solids corresponding to these spreads was computed for each thickness and resin spread.

The combination of the above variables resulted in the experimental design given in Fig. 1.

Board Manufacture

Material: Green scarlet oak pulp bolts from 8 to 10 inches in diameter and 5 feet long were selected from a pile of pulpwood cut from the woodlands of The Pennsylvania State University in an improved operation. Bolts of the best form and quality available were selected, debarked, sawn in half, and stored under water until they were to be flaked.

Flaking: Flaking was performed on an 18-by-72-inch metal-working engine lathe in a manner similar to rotary cutting veneer. The bolt of wood, about 9 inches in diameter by 30 inches long, was held between the jaws of a three-jaw chuck and the dead center, a small hole being drilled in one end to receive the dead center. The log was then rotated against a four-inch piece of planer knife mounted on the tool rest. A spur knife was necessary to trim the flakes to the proper length. Fig. 2 shows an over-all view of the flaking operation in which the first cut is being made. Fig. 3 shows the detail of the knife holders. A short cut across the end of the log was made to true the end. The tool rest was then backed out and the carriage unlocked and moved toward the chuck a distance equal to the length of flake desired. The carriage was then locked and the cross-feed advanced by hand to trim the surface down to a circle. The cross-feed was then engaged and fed in automatically until the bolt was turned down to about a 2½-inch core. The tool rest was again backed out and the process repeated until the chuck holding the other end of the log was reached. The lathe was operated at the maximum speed it could maintain under load. The material as it came from the lathe was in the form of long ribbons. Subsequent handling and tumbling during drying served to break up the ribbons into flakes of acceptable width in some, but not all, sizes. Flake thickness was controlled by selecting the proper feed rate from the large number available.

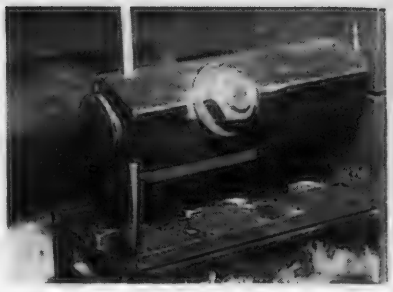

Fig. 3.—Detail of cutting tool used to produce ribbons.

The flakes were placed in drums covered on the outside with wire mesh to permit circulation of air around the chip mass and dried in a small laboratory dry kiln at 190° F. without steam to a moisture content of about 4 per cent. The drums were mounted in the kiln so that they could be rotated slowly to tumble the chips as they were dried. The longer, thicker flakes particularly did not break up to the proper width in handling and also were not broken up by tumbling. In some cases it was necessary to break the ribbons by hand.

Resin Application: A batch of chips weighing slightly in excess of the weight needed to form a board of the required specific gravity was charged into the mixer. In a few cases where the ribbons produced on the lathe were not broken up before this step, tumbling the chips with a couple of heavy wood blocks was effective. The batch was tumbled a short time and a moisture-content sample was taken. The oven-dry weight of the batch was determined and the weight of urea resin required to give the desired per cent resin solids based on oven-dry weight was calculated. Resin was applied by an ordinary bleeder-type, pressure-feed, paint-spray gun. The gun was connected to the air hose by a quick-coupler, which permitted detachment of the gun for weighing. Weight of resin discharged was determined by weighing the entire gun and contents on a torsion balance before and after discharge. To form a more finely divided spray, the urea resin was diluted from 65 per cent solids to 50 per cent solids. During resin application the chips were tumbled in an improvised mixing drum consisting of

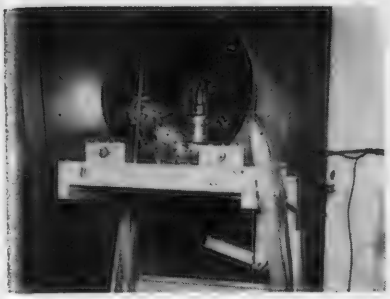

Fig. 4.—Mixing drum set-up for resin addition.

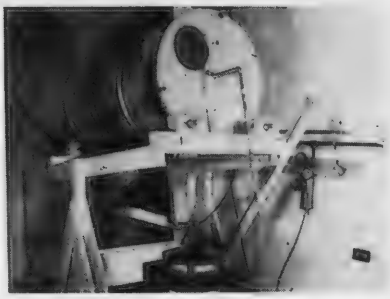

Fig. 5.—Mixing drum equipped to dry flakes following resin addition.

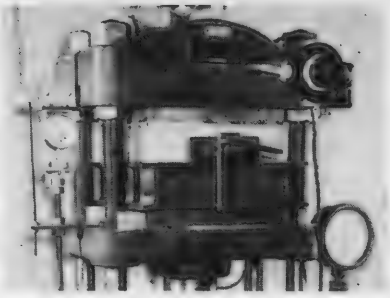

Fig. 7.—Hot press in closed position, showing caul box enclosed in steel frame and dial gage for reading board thickness.

a 55 gallon oil drum with vanes brazed to its inside surface. Figs. 4 and 5 show the mixing apparatus. Inclination of the drum was variable, and a stepped-drive pulley gave speeds of from 12 to 40 rpm. To be sure that all flake surfaces were presented to the resin spray, the discharge rate was adjusted to give a minimum spray time of three minutes. Much longer times were used with chip sizes that were particularly bulky and difficult to tumble. The question of possible loss of resin spray from the open end of the drum during mixing turned out to be of less consequence than was thought at the time.

A series of standard Kjeldahl nitrogen analyses for the nitrogen added by the urea resin showed that, on the average, about 84 per cent of the resin discharged from the gun was retained on the flakes.

Moisture Content Adjustment: After application of resin, the moisture content of the batch was again determined. This ranged from about 6 to as high as 22 per cent in a few cases due to the tremendous differences in resin content. It was desired to maintain the moisture content at time of pressing to 10 per cent plus or minus 0.5 per cent. When the batch moisture content was below 10 per cent, water was sprayed in from a second spray gun in a manner similar to that used in resin application. When moisture content was above 10 per cent, it was necessary to dry the batch in a short time without the application of heat so as to avoid precuring the resin. The solution to this problem is shown in Fig. 5. A cover was placed over the open end of the mixing drum, and compressed air was introduced at the back of the drum through a length of pipe extending through the cover to the bottom of the drum. Before entering the drum, the compressed air was passed through a bed of calcium chloride in an inverted bell jar to remove moisture. The drum was rotated at its slowest speed during drying. Fig. 6 shows a sample of each flake size taken from one resin group.

Forming and Pressing: The weight of chips required to form a board of 0.65 specific gravity (weight and volume oven-dry) was calculated and weighed. The board was formed by hand in a 10-by 10-inch caul box about 5 inches deep. When necessary to reduce the mat down to five inches for it to fit into the press opening, the mat was prepressed under the jack screw of a gluing clamp. The caul box was fitted inside a pre-heated steel frame, and the whole assembly was placed in the small hot press and the press closed. Fig. 7 shows the closed press with the frame and caul box. The press was closed as rapidly as possible to a thickness of 0.75 inch. Thereafter, pressure was adjusted to maintain this thickness. Curing time was 15 minutes at 275° F., after which the board was removed from the press and cut into static bending test specimens, as shown in Fig. 8. Fig. 9 shows a sample of board manufactured from each chip size.

Testing: Specimens were conditioned to equilibrium at 50 per cent relative humidity. Insofar as was possible, static bending tests were performed in acordance with ASTM D 1037–52T. The only major deviation was a reduction of span from 18 to 9 inches necessitated by the small size of the panels. With a few specimens of larger chip sizes it was necessary to reduce the span still further to avoid having a very poor edge at the supports. Immediately after each specimen was tested in bending, the specific gravity and moisture content sample was marked out and the screw withdrawal test was performed at its center. After this the specific gravity and moisture content sample was cut and treated as usual.

Results and Analysis

The modulus of rupture and specific gravity results of these tests are given in Table 1. This table notes the occurrence of horizontal shear failures in some specimens due to the short span, particularly in those made up of flakes 4 inches long. The modulus of rupture of specimens failing in this manner was computed by means of the load at shear failure as though failure had occurred in tension. The true modulus

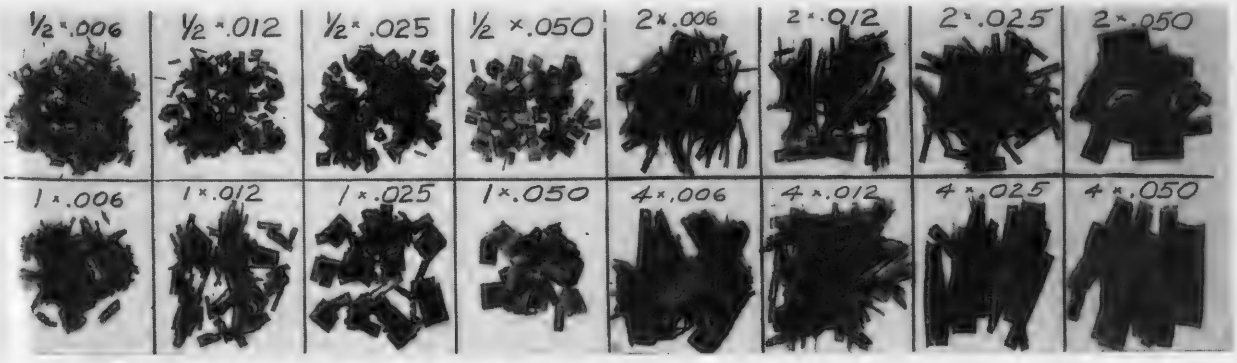

Fig. 6.—Sample of chip sizes included within one resin level.

Table 1.—UNCORRECTED MODULUS OF RUPTURE AND SPECIFIC GRAVITY

Resin spread	Length	Specimen	Flake thickness 0.006 MOR	0.006 Sp. gr.	0.012 MOR	0.012 Sp. gr.	0.025 MOR	0.025 Sp. gr.	0.050 MOR	0.050 Sp. gr.
Low	½	A	3810	0.756	2598	0.674	913	0.616	574	0.644
		B	2922	.741	2602	.683	837	.612	544	.654
	1	A	3130	.698	4366[1]	.716	2380	.650	512	.667
		B	3562	.631	3904	.701	2165	.720	659	.620
	2	A	4037	.670	3679[1]	.761	1196	.698	1742	.681
		B	3250	.650	2451	.574	1593	.613	2127	.660
	4	A	2878[1]	.713	2829	.834	2282[1]	.716	1126[1]	.684
		B	2813[1]	.716	2908	.831	1962[1]	.681	2137[1]	.657
Medium	½	A	2809	.617	2420	.668	1650	.661	621	.682
		B	3034	.603	2562	.666	736	.573	486	.650
	1	A	5154	.694	3379	.688	2067	.655	996	.625
		B	5400	.716	3486	.616	2013	.677	1129	.634
	2	A	4128	.629	4150	.649	2165	.581	1428	.593
		B	4337[1]	.702	7848	.788	2399	.651	2092	.669
	4	A	3117[1]	.708	7752[1]	.771	4911[1]	.687	2175[1]	.672
		B	2543[1]	.641	5285[1]	.615	4707[1]	.731	3008[1]	.654
High	½	A	3907	.651	2566	.638	1666	.611	1190	.666
		B	4630	.596	2274	.618	1289	.578	1166	.676
	1	A	4068[1]	.663	4804	.718	2278	.666	1131	.627
		B	3227	.635	3285	.642	3056	.698	1599	.660
	2	A	4128	.621	6917[1]	.755	3482	.632	3143	.660
		B	5038	.682	5942[1]	.705	4460	.708	3200	.750
	4	A	3170[1]	.601	9765[1]	.816	6518[1]	.808	4534[1]	.689
		B	4302[1]	.757	7106[1]	.741	4524	.614	1467	.522

[1]Failure occured in horizontal shear. MOR was calculated by means of maximum load at failure.

of rupture was certainly no less and was probably greater than that computed in this manner.

In any study of this nature, the effects of changes in specific gravity can become over-riding unless specific gravity is either closely controlled at the time of board manufacture or the effects of changes in specific gravity are removed by some statistical technique. In this investigation, it was hoped that specific gravity could be controlled closely enough to be considered constant. The values in Table 1 indicate that this was not the case, and that some rather large changes of modulus of rupture that occurred within a panel were at least partly due to changes in specific gravity.

Before the modulus of rupture data were analyzed and interpreted, the effect of specific gravity was in part removed by the following method. The slope of a straight line fitted by least squares to the within-board changes of specific gravity and modulus of rupture was determined. The slope determined for all boards was 11,600 psi per unit change of specific gravity. Each modulus of rupture value was corrected to the average specific gravity of all specimens (0.672) according to the equation:

Corrected MOR = MOR — 11,600 (specific gravity — 0.672).

This method ignores possible interactions between specific gravity, MOR, and chip geometry. It was felt that the data were too limited and too erratic to justify fitting separate regression lines to changes of specific gravity and MOR for different chip geometries. Table 2 gives the corrected MOR of all specimens tested.

It was also noted that the long flakes were not breaking up to the proper width, but instead were folding and curling in a manner making it impossible to deposit resin on the inside of the folds and curls. The effect that this action would have upon the test results was not fully recognized at the time of board manufacture, and, unfortunately, a large number of panels were made before steps were taken to eliminate this factor. Costly as the loss of these data were, MOR values affected by the folding and curling of the flakes could not logically be included in an analysis of the effects of the three main variables.

Two other variables that were known to be operating but whose effects could not be removed either by control at the time of manufacture, statistical techniques, or the elimination of data will be discussed next.

Attempts were made to distribute the resin over the surface area of the flakes as uniformly as possible. This was particularly difficult on long flakes, and the resulting poor resin distribution is thought to be the cause of the large number of shear failures in the 4-inch flake-length group. The urea resin used throughout the study was stained with pyronin B dye to give a visual indication of resin distribution. Most flakes had some resin on 85 to 90 per cent of their surface area. Sixty-five per cent coverage was about the minimum and 100 per cent was maximum. Observation under a binocular microscope revealed that resin tended to be deposited on any loose fibers torn from the surface; however, loose fibers were present to a small degree in the 0.050-inch thickness group only. Variation in resin coverage appeared to be distributed throughout the experimental design in a random fashion.

Table 2.—CORRECTED MODULUS OF RUPTURE—PSI

Length	Specimen	Resin spread: Low, Flake thickness 0.006	Low 0.012	Low 0.025	Low 0.050	Medium 0.006	Medium 0.012	Medium 0.025	Medium 0.050	High 0.006	High 0.012	High 0.025	High 0.050
½	A	2834	2567	1563	899	3448	2466	1778	504	4161	2961	2375	1210
	B	2121	2474	1534	753	3835	2631	1886	741	5513	2901	2381	1119
	Av.	2477	2520	1548	826	3642	2548	1832	622	4832	2931	2378	1190
1	A	2828	3855	2636	570	4898	3193	2264	1542	4173	4270	2348	1614
	B	4038	3567	1607	1263	4889	4136	1955	1570	3657	3633	2754	1763
	Av.	3433	3711	2122	916	4893	3664	2109	1556	3915	3952	2551	1696
2	A	4060	2645[1]	894	1637	4627	4417	3152	2346	4720	5953[1]	3947	3252
	B	3506	3589	2278	2266	3989[1]	6501	2643	2133	4899	5559	4042	2294
	Av.	3783	3117	1586	1952	4308	5459	2898	2240	4809	5756	3994	2778
4	A	2402[1]	947	1771[1]	1023[1]	2699[1]	6602[1]	4737[1]	2175[1]	3995[1]	8092[1]	4938[1]	4107
	B	2302[1]	961	1857	2311[1]	2903[1]	5947[1]	4022[1]	3217[1]	3315[1]	6305[1]	5198[1]	3339
	Av.	2352	954	1814	1667	2801	6274	4379	2696	3655	7198	5068	3723

[1]Failures occurred in horizontal shear. Modulus of rupture was computed by means of the maximu load at shear failure.

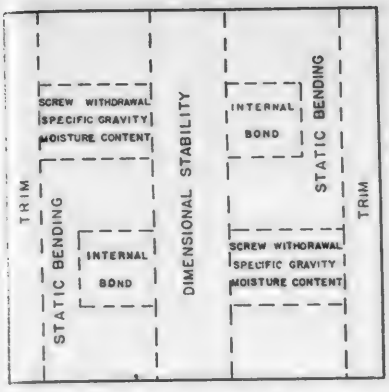

Fig. 8.—Pattern followed in cutting specimens.

Table 3.—ANALYSIS OF VARIANCE OF CORRECTED MODULUS OF RUPTURE DATA[1]

Source	Sum of squares	Degrees of freedom	Mean square	F	Term against which effect was tested
Main effects					
Resin spread	4,078,668	1	4,078,664	17.7[2]	Combined 3-factor interaction and error term
Length	63,385,629	3	21,128,876	21.2[2]	
Thickness	56,943,540	2	28,471,770	35.8[2]	Length × thickness interaction
Two-factor interaction					
Resin—Length	587,174	3	195,725	N.S.	
Resin—Thickness	97,351	2	48,676	N.S.	
Thickness—Length	4,775,764	6	795,961	3.22[3]	Combined 3-factor interaction and error term
Three-factor interaction					
Resin—Length—Thickness	379,817	6	63,303	N.S.	error term
Within boards	7,014,514	24	292,271	----	
Total	137,262,457	47			

[1]Only data free of the effect of flake curling is included.
[2]Indicates significance at 1 per cent level.
[3]Indicates significance at 5 per cent level.

The quality of the flake surface varied considerably, depending primarily upon flake thickness. Flakes 0.006 and 0.012 inch thick had surfaces comparable to well-planed lumber. The surface quality of flakes 0.050 inch thick was comparable to a surface sanded with a coarse grade of sandpaper. The absence of anything similar to a veneer-lathe pressure bar on the flaking equipment was responsible for much of this and also a large amount of checking on the "open" side of the flakes.

Flakes 0.025 inch thick were of intermediate surface quality. Since surface quality varies systematically with flake thickness, the effects that are apparently due to changes of flake thickness also include the effects of changing surface quality. The importance of surface quality in determining strength is not well understood as yet, and no attempt will be made to separate this effect from that of flake thickness.

To determine whether or not changes of thickness, length, and resin spread had statistically significant effects upon MOR, an analysis of variance technique was used. A preliminary analysis was performed based on the corrected MOR values from all boards. This resulted in a highly significant three-factor interaction. This was readily explained, not as a true interaction, but as the effect of a fourth variable, namely the folding and curling of flakes previously mentioned.

A second analysis including only MOR values known to be free of this effect was performed. This necessitated the elimination of the entire low resin spread block, and the 0.006-inch flake thickness column of the medium and high resin spread blocks. The results of this analysis are summarized in Table 3. All main effects are significant at less than the one per cent level, and a thickness—length interaction was significant at the 5 per cent level. All other interactions were not significant.

The main effects of flake length, resin spread, and flake thickness are shown in graphs A, B, and C respectively of Fig. 10. Those points which were affected by the folding and curling of flakes were not plotted. It seemed reasonable in view of the significant thickness—length interaction and the rule of thumb regarding length to thickness ratio mentioned earlier that strength might correlate well with the ratio of length to thickness. Graph D of Fig. 10 shows a line fitted by eye to a plot of MOR against length to thickness ratio.

Graph A of Fig. 10 shows a continuous increase of MOR as flake length increases from 0.5 to 4 inches. The increase averaged about 1000 psi per one inch increase in length in the range of 0.5 to 2 inches. Beyond 2 inches, the rate of increase was about half this amount. This reduction is due in part to the large number of shear failures that occurred in the 4-inch length group. The true MOR would undoubtedly have been somewhat, if not materially, higher. This group of tests would bear repeating with specimens that could be tested on the normal 18-inch span, thus reducing the shear stress at the neutral plane.

Oddly enough, increasing length as a means of increasing strength appears to be more effective with the thinner flakes, even at fairly high length to thickness ratios.

Graph B shows that resin spread has a surprisingly small effect upon MOR. Altering chip geometry so as to increase the length of thickness ratio by either increasing length or reduc-

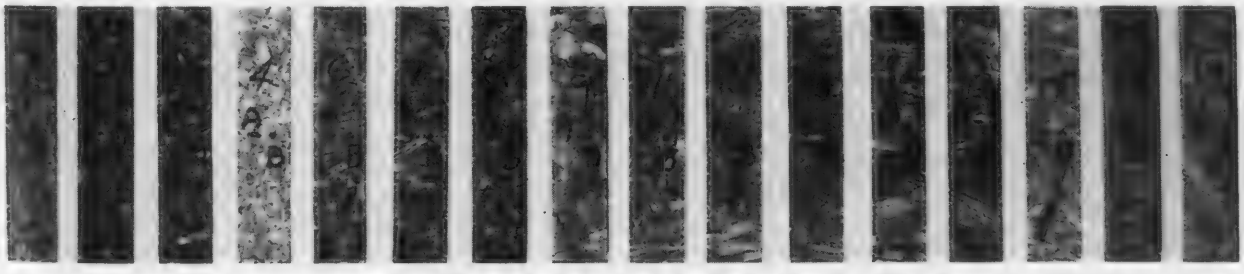

Fig. 9.—Appearance of finished board manufactured from each flake size.

Board No.	Flake size, In.	Board No.	Flake size, In.	Board No.	Flake size, In.
1	0.5 x 0.006	8	1 x 0.025	14	2 x 0.050
2	.5 x .012	9	1 x .050	16	4 x .006
3	.5 x .025	11	2 x .006	17	4 x .012
4	.5 x .050	12	2 x .012	18	4 x .025
6	1 x .006	13	2 x .025	19	4 x .050
7	1 x .012				

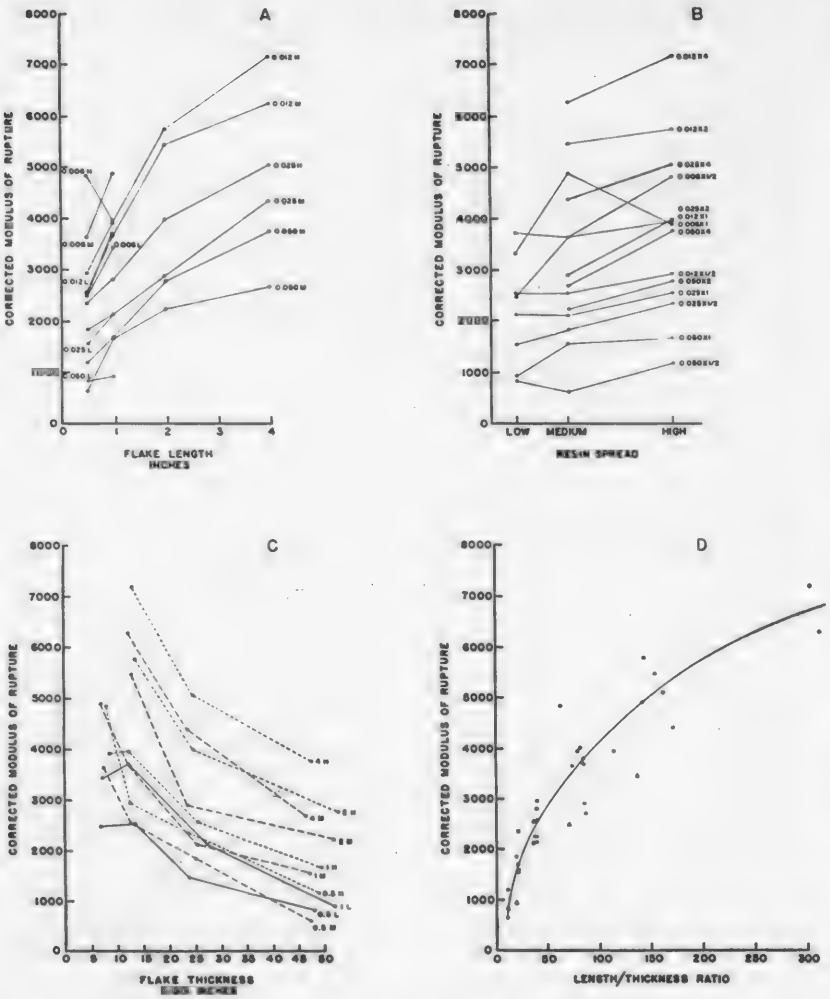

Fig. 10.—Curves showing the relationship between modulus of rupture and experimental variables. Numbers identifying each curve refer to flake size (length and thickness in inches), and letters indicate resin spread (low = 3.27 g/M², medium = 6.54 g/M², high = 13.07 g/M²).

ing thickness would be more effective in increasing strength than would increase the resin spread. Reducing thickness would require an increase in per cent resin used, whereas an increase in length would not. Since resin is a major item in the cost of manufacturing particle board, increasing length might be advantageous if the attendant problems of resin application, handling, and forming can be dealt with at less cost than would be incurred by increasing resin content.

Graph C shows a rapid increase in strength as thickness increases from 0.006 to about 0.025 inch, and a less rapid decrease between 0.025 and 0.050 inch. It must be born in mind, however, that these curves may be affected considerably by systematic variations in surface quality of the flakes as thickness increases. In addition to the effect of surface quality, the decrease in strength with an increase in chip thickness may be attributed to a decrease in the pliability of the thicker chip resulting in a poor mating of the chip surfaces, or to the presence of pronounced stress concentrations at the gaps occurring at the ends of the thicker flakes. This latter explanation was advanced by Clark[5], who reported that the use of tapered flakes to eliminate these gaps resulted in substantial increases in bending strength.

The trend in graph D is a continuous increase of MOR as length to thickness ratio increases. This trend is indicated by the line fitted by eye to these points. No optimum length to thickness ratio is indicated by these data. In Table 4, particle geometries are ranked in order of their performance as measured by MOR with the length to thickness ratio of each geometry indicated in the last column. A fairly close relationship between MOR and length to thickness ratio is apparent. It is also interesting to note that, within a length to thickness ratio class, thinner flakes seem to perform better. On the other hand, increased pliability, better mating of thin flakes, and the absence of gaps at the flake ends may be entirely responsible.

[5] Clark, J. d'A. 1955. A new dry process multi-ply board. Forest Prod. J. 5:209–213.

Table 4.—COMPARISON OF RANK OF PARTICLE GEOMETRY BASED ON MODULUS OF RUPTURE AND PARTICLE LENGTH TO THICKNESS RATIO

Rank by MOR	Flake size, inches	Length to thickness ratio
1	0.012 x 4	333
2	.012 x 2	167
3	.025 x 4	160
4	.012 x 1	83
5	.025 x 2	80
6	.050 x 4	80
7	.012 x 0.5	42
8	.050 x 2	42
9	.025 x 1	42
10	.025 x 0.5	20
11	.050 x 1	20
12	.050 x 0.5	10

Attempts to define empirically the nature of the relationships of graphs A, B, C, and D more accurately as logarithmic, reciprocal, or some combination of the two were largely unsuccessful.

Conclusions

With as many uncontrollable variables entering into the experiment as do here, the extension of the results of this investigation to the general situation is risky. Nevertheless, the following conclusions seem justified.

1. Longer flakes give higher strength up to a length of 4 inches. Increasing length would be an effective and economical method of increasing strength without increasing resin content if the many mechanical problems in handling long flakes could be overcome.

2. Resin content, though easily varied, is not as effective as flake size for controlling the strength in bending of flake-type boards.

3. The application of resin on the basis of particle surface area rather than weight appears to be a reasonable method of separating the effects of particle geometry from resin spread in experimental work.

4. Flake thickness may be considered very important in determining the strength in bending in spite of the fact that, in this experiment, the thickness effect was confounded with surface quality.

5. Strength is fairly well related to the length to thickness ratio of the particles, and shows a continuous increase up to a ratio of at least 300.

Guided by mobile radio, this rugged 4-wheel-drive truck can "go anywhere, any time."

Unattended radio repeaters operate continuously, even when buried by snow on high mountains.

Mobile Radio . . .

NEW TOOL IN LOGGING OPERATIONS[1]

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The use of radio is not a matter of buying apparatus, but of gaining the privilege to use specific radio channels that are a public resource. FCC not only issues licenses for technically regulating radio systems, but also specifies the nature of communications and the extent of its use. Protection of life and property takes first priority. The cost of $600 per mobile unit may seem high, but the gain in a single emergency often justifies the total expense of a radio system.

WORLD WAR II INTRODUCED a new era and the mobile concept of radio communications. Bombers, fighters, ships, tanks, infantry, guns and supplies were moved toward an objective coordinated and timed by the one tool—mobile radio. Never before in history had such concentration been possible in warfare, nor had warfare ever before become so mobile. World War II was fought on the land, sea and in the air through mobile radio. Most of this occurred quite unknown or slightly heard and appreciated by the general public. As the war drew to a conclusion, stories began to break of the many heroic events in the world-wide battle field and always, in the background, was the coordinator, mobile radio.

Prior to this war, police radio was about the only public concept of mobile radio. During the period just prior to and during World War II, great segments of the logging industry abandoned its horse and hand methods in favor of modern construction machines, heavy trucks and tractors adapted to logging. Throughout the war, these new-type logging machine operators working in remote forests were constantly plagued by the lack of communications to gain supplies, assistance, and repair parts for their new fleets of improvised machines. There were inefficient, mechanical troubles contrasted with high production demands of the war. Many loggers recognized the need of communications. A few sensed the similarity between directing a logging job flung over hundreds of square miles of mountains or swamps with a minimum network of roads as being comparable to the movements of the military. Coordinated communications was essential in mobile machine logging, and the new war-time two-way radio seemed the answer.

Radio is a Public Resource

Loggers who wanted radio found road-blocks. If they got a radio licensed, it in turn specified a new intangible thing called a radio channel defined in technical terms. Trying to unravel the technicalities of licensing procedure for radio was enough to discourage anyone already dismayed by the new mechanical intricacies of new-type logging machines.

A committee was formed at the Pacific Logging Congress on the West Coast to investigate the practical possibilities of loggers getting mobile radio. The Federal Communications Commission and their patient staff gave kindly advice to this forest industry radio committee on the procedures and details of gaining the privilege of using two-way radio. It was soon very evident that it was not a "right to use" to use radio, but a "privilege to use" a very small segment of a public resource known as radio channels, which was controlled by the Federal Communications Commission (FCC). Public interest, convenience, and necessity had to be proved and continuously lived up to under the Federal Communications Act of 1934.

The radio committee accepted this challenge. They were assigned tem-

[1] Presented at Session IIa, Logging, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

The Author: Robert Olin holds a BS in electrical engineering from the University of Idaho, and has held various positions with Potlatch Forests in both mill and woods engineering. He is past president of the Intermountain Logging Conference.

porary use of certain channels while the industry formed a national organization. The committee was sponsored by the Forest Information Council and the Pacific Logging Congress. Loggers learned for the first time that they gained the privilege of using radio not by buying a piece of intricate, complicated electronic gear, but by first earning a privilege of using a public resource in a manner compatible with public interest. This meant that, in times of public emergency and in dealing with employees of the industry as the public, it was necessary always to consider their welfare and safety and to use mobile radio first to protect life and property. In 1949, FCC created the Forest Products Radio Service.

Forest Industry Radio Communications

Today, the National Executive Committee of the resulting organization of radio-using logging industry members is called Forest Industries Radio Communications (FIRC), and it guides the day-by-day contact between forest industry members and the FCC. The entire engineering detail of assigning a mobile radio channel to any particular logger or industry user must clear through a division office of FIRC before the Federal Communications Commission considers the applicant's request for a radio station license. This office maintains all of the license records and engineering data for *every private forest industry radio* system in the United States.

The nation is divided into four divisions: Eastern, Southern, Lake States, and Western. A separate voluntary committee guides the affairs of each division in recommending individual company channel assignments. Policy development and coordination of divisional efforts are carried on through the national office located in Eugene, Oregon, and operated by a Secretary-Manager, directed by the National Executive Committee. All forest industry radio users or potential users are considered members of FIRC. Those that pay a small annual fee for each radio they operate do become voting members and directly participate in the affairs of the organization, and receive services in addition to channel recommendations.

Use of Radio

People not acquainted with mobile radio worry about the technicalities, electronic terminology, and the unknown complications of maintaining such equipment. These worries and fears are unfounded. The high degree of manufacturing skill and sales-engineering know-how built into well-known and reliable makes of equipment make possible the purchase of mobile radio system as a package.

Next, the maintenance is usually well handled by those manufacturers' local representatives operating their own shops, or by some of the great army of electronic technicians trained by the government during the war period now running their own shops. The FIRC committee gains your privilege of using mobile radio as an industry, then aids with license applications, rule changes, and so forth, thus simplifying the procedures for the logger. The maintenance is handled by local technicians of the user's choice. Therefore, the use of mobile radio has become as commonplace as the use of tractors in the forest industry.

Government Limits Radio Uses

Part of every government grant of radio license indicates the type and nature of communications that can be transmitted by stations operating under that license. Profanity, false signals, and other illegal signals are strictly barred under heavy federal penalties. The forest industry is limited to a general rule that permits "communications necessary and incidental to the operation of the business", giving first priority to the safety and welfare of its employees, the public, and protection of property. Personal communications and other foreign types of communications for third parties are definitely not permitted. FIRC has Operators Manuals to guide your use of radio.

Forest Industry Radio Uses

The many favorable and useful applications of mobile radio are limited by the ingenuity of the loggers. They are without limit. Of first importance is that of gaining assistance for those that are injured or lost in the forests. Roads are cleared for ambulances or for emergency runs by doctors. Airplanes are frequently called to transport injured persons to hospitals. It is estimated that at least ten lives are saved every year in industrial forests due to the time gained through rapid communications by mobile radio. The second primary use is that of fire protection work. Fires can be detected, but unless adequate help can reach the fire quickly the loss can be great. Mobile radio plays two parts, first it sounds the alarm of those detecting the fire and measuring its severity. Next it mobilizes men, machines, and transportation to subdue and control the fire. It mobilizes supplies and reserve equipment to back up the first line of fire defense. The effectiveness is quite like that of the military, where all forces become fluid and flow toward the target area.

Beyond these emergency uses come the routine business of tree farming and logging. Machine breakdowns and repairs are one constant source of emergency. Direction of crews and shifting of machines from one area to another are accomplished by one supervisor working from his car or pick-up in the area, even though he may never reach the site where the changes occur. Routine administrative matters and procurement of necessary parts and supplies take the last place in the category of priorities, but aid tremendously in justifying the cost of mobile radio systems.

Radio Equipment

Mobile radio systems vary greatly in complexity. Usually there is a home or base station, which may be located at a general office, headquarters or mill. Most mobile radio is a line-of-sight type of signal transmission, so often times this base station antenna must be located high on a tower or on a hilltop near the headquarters office. The radio equipment up high is connected by land wires to the office. Another radio system that would displace the land wires is used where land wires are too expensive, this being called a control radio. Large systems may require several base stations to adequately cover the logging operation, and in many instances these base stations are tied together by means of secondary radio channels assigned for that specific base-station use. Normally radio service is a mobile service that restricts base stations to communicate with mobile units or communications between mobile units.

Mobile radios can be installed in any battery-powered vehicle. Low-power mobiles, called pack-sets, carry their own battery power in dry or re-chargeable carry-type batteries. Range of communications is controlled by many factors, but the usual distance is 10 to 25 miles from the base station, although there are many exceptions and qualifications to this figure. Some radios are installed in log trucks, in log-loading machines, or may be set up as temporary base stations with a mobile gasoline-engine-driven power plant to power them. On rivers where logs are boomed, the loggers can use forest industry radio to control the boat's operations. The airplanes that are used for fire detection or other forestry purposes can also be so equipped.

Radio Costs

The average mobile radio cost between $500 and $600 installed in a car or truck. The simple base station with

its antenna and necessary equipment will run between $1,000 and $1,500. This base station price will be increased when it is remotely controlled on some mountain top where weather elements require better housing. Low-power, short-range hand-packed battery sets may be purchased for as little as $300. Such pack-sets are invaluable on fire lines. Maintenance costs vary greatly with the local availability and capabilities of FCC licensed technicians that are required. It may range anywhere from $5 to $20 per set, per month, depending on type of service and equipment, with the average of about $12 per set per month.

Many firms report that the savings on a single emergency or situation have frequently paid for their entire radio system in one experience. Mobile radio has become an indispensible tool of private forestry. Men employed by the industry in remote forests demand adequate contact with medical and emergency assistance from the outside world, and it is the only tool by which the complex machinery of logging can be efficiently coordinated to do the rugged job of removing timber from the forests.

Electronic Forestry Future

The future of the uses of radio as a forest industry tool are brilliant. A new-type beamed radio, known as microwave, provides a new possible tool for coordinating forests, mills, offices, and machines. The forest industry is a natural to adopt accounting machines and electronic-brain devices to its complex job of growing and harvesting trees and producing this timber crop into useful products. Microwave and mobile radio will provide the means of assembling huge quantities of data that can be entered into business machines, computed, and the answers returned at extremely low cost with a great reliability. The problem and the techniques are yet to be developed, but the real values of the use of radio still lies ahead for the industry.

Discussion

H. I. Winer (Yale School of Forestry): You mentioned that only one of five wishing to use radio is assigned a channel. How does the FCC decide who gets the channels?

Mr. Olin: Assignment of channels is based on an evaluation of the applicant's need, and how the assignment would serve the public interest. Availability of channels is limited, and in many areas there just aren't enough to go around. This creates a real problem of establishing priorities for assignments.

Chemical Foam Extension

OF UREA-FORMALDEHYDE GLUES[1]

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The advantage of foamed resin is lower cost. In effect, air or inert gas serves as a filler, which escaped during bonding without harmful effect. "Chemical" foam is more stable than "mechanical" foam. Spread should be between 15 and 25 pounds per thousand square feet of single glue line.

THE IDEA and actual investigation of the use of a resin in the form is not new. It began even prior to World War II. The original idea was born in Germany, where the present urea-formaldehyde resin was also developed and adapted for plywood bonding.

The interest and the basic reason for this interest in the development of a foamed resin was the same 20 years ago as today. These basic reasons are of an economic nature. The urea-type resin was immediately accepted as an almost ideal resin for use in the woodworking field, and was enthusiastically approved. The only drawback was the cost, controlled by the high cost of raw materials at that time. Various fillers and extenders have been tested, but it was found that they either reduce the quality of the bond, are in short supply, or are still too expensive.

A similar situation exists today. Although the cost of raw materials is rather low today and the cost of the resin is at its lowest level, still the competitive situation on the finished product requires a fractional cost control of each of the components, including the resin. At the same time, however, when prices on the finished goods are on the down grade, the quality level climbs. Therefore, the competitive struggle involves not only the price, but also the quality.

The problem facing resin-adhesives is the same. The cost of the adhesive can hardly go down; therefore the question is, "how to use it in the most economical and efficient way without imperishing its bonding properties and meeting the high quality standards?

Foaming of the adhesive before its use seems to offer the ideal solution. It represents an entirely revised approach to the formulation and action of the resin glue. We can readily see this when we compare the foam formulation with a standard one such as generally adapted by the industry now. The standard urea-formaldehyde resin, as supplied at the present time by various resin manufacturers, can be used "as is" only with great difficulties due to its excessive penetration. This is especially true in the common hot-press operation, where the resin becomes excessively thin under the influence of heat.

This penetration can be controlled only to a certain degree by compounding with a suitable curing-catalyst, which will promote a greater polymerization speed (cure) and thus reduce penetration. This approach, however, results in a danger of precure and in a sacrifice of other properties, such as pot life or assembly time.

Fillers and Extenders

The only remaining way is the use of suitable fillers and extenders which, at the same time, reduce the cost of the resin-glue mix. Shell-flours have been introduced, and their use is beneficial in bodying the resin and thus reducing the danger of over-penetra-

[1] Presented at the Carolinas–Chesapeake Section Meeting, held Nov. 30, 1957, in Roanoke, Virginia.

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Fig. 1.—Urea-formaldehyde glue mix before addition of the foaming catalyst.

Fig. 2.—Glue mix two minutes after the addition of the foaming catalyst.

tion and difficulties such as bleeding and staining. If the glue formulation is not carefully controlled, the resin is usually filtered out by selective absorption, leaving shell-flour in the glue line. However, the main problem with shell-flour is that only a very limited amount can be used to obtain a workable mix and a satisfactory bond. Shell-flour is therefore used rather as an aid to control the performance of the resin glue.

Cereal flours represent the generally accepted extender used in various proportions throughout the industry. Flour will unquestionably reduce the cost of the resin mix considerably. Flour reacts with the urea type resin and therefore cannot be completely filtered out from the glue line as the fillers are. The flour also helps control the penetration. On the other hand, however, flour presents serious problems. Flour is very non-uniform due to natural reasons. It varies from supplier to supplier, from season to season, and even from batch to batch. Flour requires at least an equal amount of water to give a spreadable consistency. This additional water is then released in substantial proportions in the glue line and veneers, adversely affecting the properties of the finished construction by weakening the fibers and affecting the dimensional stability. Flour slows down the reactivity of the resin, which means it slows down the cure. Flour-extended resin definitely has a lower water resistance, a lower strength, and gives a bond susceptible to attack by various fungi and bacteria, and deteriorates under unfavorable climatic conditions.

The most important problem, however, is that of the spread. Flour has no bonding properties, and it interferes with the flow of the resin under pressure and heat and consequently with the transfer. To overcome these difficulties and to have a sufficient amount of resin in the glue line, it is necessary to apply higher spreads. A customary spread of 45 to 55 pounds of glue mix per 1,000 square feet of single glue line causes an excessively thick glue line, introduces too much moisture, and reduces the service life. Heavy spreads and wasteful practices make any cost saving of extending glue lines rather questionable, in addition to the risky quality of the bond and service life.

Extension with Air

This situation called for an adhesive that could give all the benefits of a low-cost extension and yet could maintain the higher quality of the product. Extension with air or an inert gas seemed to present an ideal approach. Resin applied in foam form offers an increased volume in the phase when this volume is needed. This volume shrinks in the glue line as soon as the job is completed without causing any adverse effect whatsoever. In these modern times, the foaming technique is very popular, and is applied in various fields when an increase of volume is desirable, such as in the field of insulation.

In view of these obvious benefits, a question is frequently being asked, "Why was this idea, which was conceived about 20 years ago, not practiced on a wide scale?" The explanation is not a single one. It is a fact that it is being practiced in some countries, such as England, Germany, and Russia, and, to a greater extent, in Finland, which is especially known for its high grade plywood. It is also a fact that foam extension is not as simple as it may sound. It requires a great deal of development and educational promotion to work out all the details, to formulate a mix that fit particular conditions existing in various plants and to adjust the existing equipment, existing techniques, and practices.

Since there is no significant past or present history on the use of a foamed resin glue in this country, this paper will refer to the approach our organization is using in introducing a foam-extended adhesive. We undertook the task of studying the reasons for the apparent resistance to the use of a foam-extended resin and to the apparent results that have generally not been too encouraging in the past. The benefits offered by a perfected method are very great, almost striking, and we believe that eventually everyone will be sold on "foam extension".

The pioneering is both difficult and expensive, and requires coordinated work, patience, and the interest of both the supplier and user. The variations in plant conditions are so great that it is almost impossible to obtain perfect results right from the start. Some initial disappointments, and even some initial failures, are to be expected. Some answers can only be found in the user's plant and some adjustments made on the spot. The ultimate results are most encouraging, however, and pay for themselves both in savings and quality.

The original approach in foaming the urea resin was to take a conventional resin syrup and beat in air under high-speed agitation until a certain volume increase took place. This method presented several short-comings and disadvantages.

First of all, a special high-speed agitator was necessary to foam the resin. Additional equipment such as an intermediate storage tank for the foamed resin was a part of the setup. Furthermore, the performance depended too much on the consistency and the amount of foam.

During hot weather, the viscosity of the resin dropped and the resulting foam had a tendency to become too thin, permitting the beaten-in air to escape to leave a more or less conventional resin. Under such conditions it was difficult to control the penetration. To overcome this condition, a higher

spread had to be used. This was contradictory to the main object of foaming, which was to keep the resin on the surface of the veneers and, by doing this, to achieve an economical advantage.

An additional disadvantage is that the "mechanical" foam has a relatively short stability and that the resin has to be used almost as soon as it is foamed. The foamed resin cannot be left for a period of time such as, for instance, overnight. Once the foam disappears, the resin must be returned to the foaming equipment for a repeated cycle.

The non-uniformity of the foam and the resulting variations in performance have been mainly responsible for the limited interest and acceptance of the foaming method. A review of these short-comings indicated a different approach to the foaming problem.

Fig. 3.—Spreading with the foamed resin glue.

High Molecular Weight

First of all, it seemed that the resin should be formulated in a different way for the foaming application rather than to be of the conventional type. In particular, such a resin formulation should represent a high-molecular structure—not only to be able to hold the foam under wide temperature range, but also to be rather independent of the character of the foam itself. In other words a resinous material was formulated which by itself has low penetrating properties and will work quite well, even without a foam. The foam is an important and valuable technical and economical aid rather than the prime object. The foam helps only to obtain the optimum performance and to reach the ultimate goal.

Another alternative to such resin especially tailored to obtain the fullest benefit from foaming would be to use a standard resin and prepare it for the foaming job. This could be accomplished by modifying the standard resin before use by using various additives to give a higher molecular structure. The present experience, however, shows that such a compounded resin is inferior to the resin "tailored" for foaming.

Another endeavor was to eliminate the use of special equipment. The specially formulated resin makes the use of a high-speed agitator unnecessary, since this resin holds the foam. The resin is mixed in a conventional glue mixer at conventional speeds. There is no technical objection against the use of air for foaming purposes with the special resin. This air can be beaten in with the help of a lightening agitator or released from a compressed-air cylinder. It was decided, however, to use a chemical foaming method with the help of an inert gas formed through the action of the foaming catalyst on the curing catalyst and partly on the resin itself. This gas is therefore formed right in the resin mix itself, and surrounds almost every resin particle. It is almost impossible to accomplish this by introducing a gas from an outside source. The minimum amount of gas is also used. At the same time, the foaming catalyst acts as a buffer and can be used along with the curing catalyst for controlling the curing speed, pot life, assembly time, and the degree of flow and penetration. The especially formulated resin, together with the use of a gas-forming catalyst, is a special feature of this approach.

In contrast to the "mechanical" foam, the "chemical' foam is more stable. A certain amount of foam can be observed even after an over-night storage, depending on existing conditions and on formulation of the mix. Internally formed foam is finely distributed throughout the mix after many hours of storage. Furthermore, such a stored resin can be easily refoamed to the original state by an additional small amount of the foaming catalyst and also possibly a curing catalyst. This refoaming can be done prior to use by a simple mixing with the help of a wooden paddle. It was also observed that the addition of a foaming catalyst at this late stage has a rejuvenating action on the resin, and lowers its viscosity. The chemical foam can be easily controlled to suit the penetration requirements of the wood species used. A "small' foam can be used on denser woods, such as, oak, maple, birch, and so forth to promote some penetration for proper bond. A "thicker" foam can be created to prevent an excessive penetration by absorbent species. It is rather difficult to achieve such a control with a "mechanical" foam.

The formulation of the glue mix is very simple and very conventional. Necessary components, such as the resin, the curing catalyst, and the foaming catalyst, are mixed together. The foam forms almost instantly—as soon as the foaming catalyst is introduced. The resin mix can be used immediately, or it can be left for a period of time, depending on the formulation and on the ratio of catalysts.

It is permissible to use a very limited amount of filler or an extender to emphasize certain properties, or to further reduce the cost of the mix. Prime conditions for the use of flour are to keep the penetration and loss of glue to a minimum. Such conditions are created by very porous, absorbent, or dry wood.

In the case of rough cuts and uneven surfaces, or in case of low available pressures, it is advantageous to thicken the mix and to thicken the foam by filling the resin rather than by increasing the spread. The foamed mix is then transferred onto a conventional rubber roll spreader by any means, such as gravity flow or circulating pump. It is also possible to spray the foam with excellent results by the use of conventional spraying equipment. The foamed resin shows a behavior similar to any other foamed material.

The resin loaded with gaseous particles appears to be quite heavy and thick on standing. This consistency, however, is only an apparent one and

is misleading since, as soon as the material is stirred, the arrested gaseous particles can escape freely and the foamy material becomes thin. It is evident, therefore, that the amount and the apparent viscosity can be controlled by agitation. For instance, foam fed to the roller by gravity flow will be thicker than that transferred by a circulating pump. The rotation of the spreader with its mixing action keeps the foam in a free-flowing and transferring condition. The specially formulated resin with its large molecular character retains finely distributed gas particles for a long time even under agitation.

It is common knowledge that a proper and uniform spread is almost the most important condition for obtaining a quality bond; otherwise, the resulting bond will be starved, spotty, or crazed. Therefore, the condition and workability of the spreader is of utmost importance for the proper performance of the foamed resin, since both the economy and quality depend on the amount and uniformity of the spread.

Up-to-date experience shows that the spread recommended for a chemically foamed resin of the type developed and described above should range between 15 and 25 pounds per thousand square feet of single glue line. Such a low spread can easily be obtained with a foamed resin and uniformly controlled if a spreader in proper conditions, with 18 to 20 grooves per inch, is used. Beside the condition of the spreader, the condition of the veneer is critical for proper results with such low spreads. The veneers should be flat, smooth, and have the proper moisture content. With all these conditions satisfied the required spread of 15 to 25 pounds gives a bond completely satisfactory in every respect and even superior to the bond obtained with higher spreads. The foam is what makes it possible to use a low-range spread. As soon as the spreading is completed, the main task of the foam as an extender ends. Soon after spreading, the foam on spreaded veneer collapses, and the gas particles escape readily, leaving only minute balloons of gas, which help to keep the resin on the surface. This is the other task of the foam. Otherwise the resin film deposited on veneers is more or less continuous.

The curing catalyst takes over the action, and the molecules begin to advance thus preventing the resin from sinking into the wood. Traces of the gas and of the foaming catalyst break down completely under the temperature in the press, and the curing proceeds in a conventional way with pressures, temperatures, and time schedules similar to those recommended for commercial urea resins.

Numerous field and control tests have shown that a properly applied, foam-extended resin, used under proper conditions, gives an excellent bond when tested both dry and after immersion in water. In most cases, the bond was actually superior, proving the known fact that the quality of the bond never depends on the amount of spread, but rather on the amount of resin binder deposited in the glue line. The quality of the bond will depend also on the quality of the binder deposited in this glue line. For instance, a customary spread of 40 pounds per thousand square feet of single glue line of a resin mix of the composition of 100 pounds of 65 per cent resin, 50 pounds of flour, and 50 pounds of water should leave 13 pounds of resin solids in this 40 pound spread. The same amount of solids is deposited in the glue line if a 20 pound spread of a foamed resin is used. And yet the glue line will not contain any flour, which not only does not contribute but even damages the quality of the bond, and will not contain an excessive amount of water, which would be absorbed by the wood with undesirable results.

Here again, field experience has shown that an even lower spread of 15 pounds and consequently a lower amount of resin deposited in the glue line by foamed resin actually gave better results because the resin was not absorbed by the wood as in the case of the flour-extended mix. It remained where it should—in the glue line. It is known that an excessixe extended spread is damaging. Only enough spread is needed to facilitate the "welding" of adjoining surfaces.

Exposure tests on panels about a year old show an excellent stability under atmospheric as well as under artificialy aging conditions. A three-ply birch veneer exposed to outside elements for a period of 13 months has still passed the 15 cycle of soaking and drying as required by the commercial standard specifications. The dry sheer strength averaged 400 psi with 80 per cent wood failure.

As to the cost and properties of the foam extended glue-line and the finished product, a typical formulation of a foam-extended resin is as follows:

100 parts by weight of resin
5–10 parts by weight of water
2–4 parts by weight of curing catalyst
0.5–2 parts by weight of foaming catalyst

The cost of this formulation is about 7 cents per pound. The cost of the same formulation modified with 15 parts of wheat flour is about 6 cents per pound.

The cost of a conventional 65 per cent urea resin extended with 50 parts of flour is 5.5 cents per pound, and a formulation with 100 parts flour extension is 4.5 cents per pound.

Comparison of Spread Costs

The glue-line cost with a conventional resin with 50 parts extension is $2.40; with 100 parts extension it is $1.90. The cost was figured on the basis of a 45-pound spread, which is below average.

A minimum spread of 15 pounds with an unextended foamed glue is $1.05, and a maximum spread of 2[illegible] pounds gives a cost of $1.75 The cost figures of a special resin reinforced with melamine are still more economical.

A typical test on panel construction containing poplar and gum veneers and glued with foam-extended resin shows a dry-shear test of 450 psi and 100 per cent wood failure, and a wet shear after 48 hours immersion of 390 psi. and 70 per cent wood failure.

All panels tested passed the minimum 15-cycles soak test as required by Specification CS–35–56, Type II.

Advantages of Foam Extension

Some of the advantages of foam-extended resin, in addition to those already mentioned, are:

Labor savings because the mix lasts longer because of low spread used and therefore a batch lasts for a longer period of time, and because it takes less time and effort to prepare it because of eliminations or reductions of fillers and extenders—(thus less ingredients to mix); less inventory, or no inventory of flour or other fillers; better water and fungi resistance; and better control of water content in the wood and resulting better dimensional stability.

Panels glued with the foamed resin were found to be flatter than those glued with a standard formulation. The acidity of the glue line is lower, which contributes to better stability in time. Less glue line gives less hardness and less abrasion to the tools.

The foamed resin is ideally suited for gluing other absorbent surfaces to wood, such as particle board, paper, canvas, synthetic fibers, or similar materials.

In resume, the experience with foam-extended resin has been very encouraging. In all cases where some difficulties or initial failures have been encountered, they could without exception be traced to improper conditions, improperly adjusted formulations, lack of initial field experience, or to just plain mistakes.

A SURVEY OF ADHESIVES FOR Edge and End Gluing[1]

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Nine adhesives and combinations of adhesives are discussed. Given for each are physical characteristics, pot life and storage life, method of mixing, approximate cost, color, and method of curing.

WHAT IS EDGE GLUING? Edge gluing, whether it be veneer or lumber, usually means the joining of two or more pieces of wood by gluing their longitudinal edges together. End gluing is the joining of two or more pieces of wood by gluing their respective transverse or cross-sectional ends together. The common joint for edge gluing is a right-angle planer or jointer cut, whereas the joint for end gluing may be a scarf joint, finger joint, butt joint, or combinations thereof.

There are several types of machines used for both types of gluing. Radio frequency, infra-red, clamp carriers, steam platen, and force fit are some of the methods employed. Table 1 shows several methods of gluing and several types of adhesives with a notation as to which adhesive can be used with a given machine. There are adhesives available for various degrees of water resistance, color, strength, and cost. A tabulation of the most commonly used adhesives is shown in Table 2.

Urea Resins

Urea resin adhesives are supplied as a water-white to opaque liquid plus a separate powder or liquid catalyst. The liquid resin is approximately 60 to 70 per cent non-volatile (PMMA), has a pot life of approximately two to six hours at 70°F., and a storage life of approximately four to six months at 70°F. The adhesive is prepared by adding the catalyst to the liquid resin and stirring until thoroughly mixed. The amount of catalyst added to the resin is generally 10 to 20 per cent of the liquid weight of the resin. The mixed adhesive costs approximately 10 to 15 cents per pound. The adhesive is water-dilutable and can be used with or without extra water, depending upon manufacturers' recommendations and particular use requirements. The color of the mixed glue can be matched to the color of a particular wood by changing the color of the catalyst used or a dye may be added. Urea resin adhesives cure rapidly by any of the conventional hot methods such as radio frequency, infra-red, or steam platen, and are also room-temperature-setting. Urea adhesives are the most versatile glues now used for edge and end gluing. For very small quantities, there is a powdered mix of urea resin and catalyst available at higher cost.

Fortified Urea Resins

Standard urea resins can be fortified to improve water and heat resistance of the cured adhesive. The amount of fortifier added depends on the ultimate properties desired, and will increase the cost accordingly. The adhesive is prepared as with a regular urea resin catalyst mix, plus the addition of a fortifier, or the fortifier may be incorporated by the adhesive manufacturer. The mixed adhesive has a color similar to that of straight urea resin adhesives, but it can also be colored to match a particular wood. The curing rate of these resins is generally slower than that of the corresponding unmodified urea resins, particularly under radio-frequency curing. The cost of these adhesives will depend, of course, on the amount of fortifier added. An excellent reference for the properties of urea resins plus various percentages of fortifier can be found in the issue of the FOREST PRODUCTS JOURNAL February, 1955. Additional data is also available from the U. S. Forest Products Laboratory at Madison, Wis.

Melamine Resins

Melamine resin adhesives are generally supplied as a white, free-flowing powder at approximately 20 to 30 cents per pound. Melamine adhesives are more expensive than urea resin adhesives but will produce a colorless

Table 1.—METHODS OF CURING VARIOUS ADHESIVES

Type of adhesive	Method of curing: Room temperature 70°F.	High temperature	Radio frequency	Infra-red	Quality: Interior	Exterior
Urea-formaldehyde resin	*	*	*	*	*	---
Fortified urea-formaldehyde resin	---	*	*	*	*	---
Melamine-formaldehyde resin	---	*	*	*	---	*
Resorcinol-formaldehyde resin	*	*	*	*	---	*
Phenol modified resorcinol resin	*	*	*	*	---	*
Double application phenol-resorcinol resin	*	*	---	*	---	*
Acid phenolic resin	*	*	*	*	---	*
Casein	*	---	---	---	*	---
Polyvinyl acetate	*	---	---	---	*	---
PVA-urea-formaldehyde resin	*	*	*	*	*	---
PVA-melamine-formaldehyde resin	---	*	*	*	*	---

*Normally cured by this method.

Table 2.—TYPICAL PROPERTIES OF EDGE AND END GLUES

Adhesive	PMMA non-volatile Per cent	Color	Pot life at 70°F. Hours	Storage life at 70°F. Months	Approx. cost per pound of mixed adhesive Dollars
Urea resin	60–70	White	2–6	6	0.10–0.15
Melamine resin	Powder	White	----------	Indefinite	.20– .30
Resorcinol resin	60	Dark red	3–6	12	.60– .70
Phenol modified resorcinol resin	50–60	Dark red	3–6	6–9	.45– .50
Double-application phenol-resorcinol resin	50–60	Dark red	2–8	1–2	.45– .50
Acid curing phenolic resin	50	Dark red	2–4	3	.15– .20
Casein	Powder	Yellow to brown	5–9	6+	.10– .15
Polyvinyl acetate	30–60	White	Indefinite	Indefinite	.20– .30

[1]Combinations of adhesives, such as urea-polyvinyl acetate, are available. Specific data depends on formulation.

[1]Presented at the Fall Meeting of the FPRS Pacific Northwest Section, held Oct. 7–8, 1957, in Portland, Oregon.

The Author: Max Estep holds a BS in chemistry from the University of Washington. He joined A–M as a control chemist in 1950, became a research chemist, and was appointed Special Adhesives Group Leader in 1953. In 1958 he became a Technical Service Group Leader for customer services gluing problems.

exterior bond. These adhesives can be added to urea adhesives at any proportion to fortify the adhesive.

These adhesives are not room-temperature-setting and must be heat-cured to obtain maximum performance. The normal curing range is from 240 to 260°F. for two to five minutes. The mixed adhesive is light colored but can be colored to match a particular wood if desired. The adhesive can be cured by hot pressing, radio frequency, infra-red, or similar heating methods. Under a comparable curing condition, such as radio frequency, melamine adhesives are slightly slower curing than urea resin adhesives.

Resorcinol Resins

Resorcinol adhesives are generally supplied as a dark red to purple liquid plus a separate powder or liquid hardener. The adhesive is prepared by adding the catalyst to the resin and stirring until thoroughly mixed. The approximate cost of straight resorcinol adhesives is 60 to 70 cents per pound, which is high, but the resultant glue line will meet rigid military and government specifications for exterior use. The mixed adhesive is room-temperature-setting or it can be cured by hot pressing, radio frequency, or infra-red to produce exterior bonds. Pigments can be added to the mixed adhesive to produce a lighter color, but the bond still is generally dark. Under comparable radio-frequency curing conditions, resorcinol adhesives are slower curing than either urea or melamine glues.

Modified Resorcinol Resins

Phenolic-modified resorcinol adhesives are supplied as a dark red to purple liquid plus a separate powder or liquid hardener. The adhesive is prepared by adding the catalyst to the liquid and stirring until thoroughly mixed. The approximate cost per pound of the mixed adhesive is 45 to 50 cents per pound. The mixed adhesive is fairly dark in color, but it can be pigmented to produce a lighter color. Curing of these adhesives requires a minimum temperature of 70°F. or preferably higher. However, exterior glue lines are produced that will meet military specifications.

Corresponding cure rates on radio frequency or heated applications show that phenol-modified resorcinol resins cure more slowly than either urea or melamine glues.

Double-Application, Phenol-Resorcinol Resins

There is also available a double-application, phenol-resorcinol adhesive that is supplied as a two-resin, two-catalyst system. Each component consists of a resin and catalyst; Resin A with Catalyst A is applied to one side of the joint and Resin B with Catalyst B is applied to the other side. When the two pieces are joined, each adhesive acts as a catalyst for the other. A fairly rapid exothermic reaction takes place and a bond is formed. This adhesive is room-temperature-setting, but can also be cured by hot pressing or infra-red. The mixed cost of this adhesive is about 45 to 50 cents per pound.

Acid Curing Phenolics

These adhesives are generally supplied as dark red liquids with separate acid catalysts. The cost of this adhesive varies between that of a urea and a modified resorcinol mix at 15 to 20 cents per pound. The adhesive is prepared by adding the catalyst to the resin and stirring until thoroughly mixed. It is room-temperature-setting, and can also be cured by hot pressing, radio frequency, or infra-red. The durability of the glue line has yet to be proven, but it is reported to be in the exterior class. There is a tendency towards more arcing on radio-frequency gluing than with other types of adhesives such as urea or melamine.

Casein Glues

These glues are supplied as powders of various colors from yellow to brown or black. The adhesive is prepared by adding the powder to water and mixing thoroughly. A short stand time is necessary before use. The approximate cost of the mixed adhesive is 10 to 15 cents per pound. The pot life of casein glues varies from 5 to 9 hours generally, but can be lengthened. The storage life at 70°F. is six months plus. Casein glues can be used at temperatures as low as 40°F. and over a wide range of moisture contents. The actual clamp time varies according to the temperature, moisture content, and type of assembly being glued, but generally several hours are required before an adequate bond is obtained. These glues produce a dark glue line because of the stain produced by the high alkalinity of the casein glue. The cured glue line produces high dry shear strength but only moderate water resistance.

Polyvinyl Acetate Adhesives

This type of adhesive is supplied as a milky white, water-soluble liquid that can be used as received or added to other types of adhesives. The PVA is room-temperature-setting and produces a high dry shear bond with low water resistance. The straight adhesive is thermoplastic, has an indefinite storage life and pot life, produces a white glue line, and is non-toxic. PVA is used as a modifier in urea or melamine adhesives to produce more flexible glue lines or faster initial tack. The cost of the PVA emulsion is about 20 to 30 cents per pound.

Conclusion

There is a wide variety of adhesives available for either edge or end gluing. The adhesive to be used for a particular operation will, of course, depend on many factors. The preceding tables give a general idea of the types of adhesives and their properties that are available for these different applications. It is recommended, however, that the adhesive suppliers be contacted for a specific recommendation for a given gluing job.

Discussion

Question: What percentage of electrolyte is best for radio-frequency gluing, especially in relation to arcing?

Mr. Estep: The percentage varies from manufacture. Salt is a common electrolyte. While the percentage of electrolyte affects the arcing properties of the glue, there are other factors that are equally, if not more, important, such as the glue spread and the squeeze-out.

Question: How are the normally alkaline (5% caustic) phenol resins for radio-frequency gluing?

Mr. Estep: They are not good; I was referring to the urea formaldehyde resins.

Question: We use polyvinyl acetate glues in medium-density overlays, and the squeeze-out creates some problems. How much polyvinyl acetate can be added to a urea-formaldehyde adhesive to reduce the show-through of hard lumps?

Mr. Estep: About 20 to 25 per cent is needed.

Question: With 20 to 25 per cent we still have problems of the lumps not melting down and flowing properly.

Mr. Estep: If too much polyvinyl acetate is added, then you will lose other desirable properties.

Question: Do you recommend adhesives for wood with moisture contents in excess of 15 to 20 per cent?

Mr. Estep: In general, no, but it depends somewhat on how you wish to cure the glue. If one is determined to glue wood at high moisture contents, then a casein glue with long clamp time might be best.

Question: Would you recommend gluing finger joints at wood moisture contents in excess of 15 per cent?

Mr. Estep: No.

Question: Can you give us estimates of costs per unit of glue line?

Mr. Estep: Not off hand. It depends too much on the individual operation.

FIVE WAYS WE CAN

Preserve Our Wood Markets[1]

C. H. Hoffman
Development Engineer, Preserving
Division Koppers Co., Inc.
Pittsburgh, Pa.

We can improve wood's position by developing better: sales techniques; variety of sizes available; products for more specific purposes; techniques to improve wood's characteristics; and processes to utilize wood residues

Pole-type construction has provided a wide-open field for wood preserves.

"PRESERVE", ACCORDING TO WEBSTER, is defined "to keep from injury or destruction" from evil"; "protect"; "save"; "to keep intact". Synonyms are listed as "guard', "shield", "secure", "uphold", "sustain", "conserve". How many times have we been told of our diminishing wood markets, warned of the ever-increasing inroads being made by competitive materials, and admonished that we must do something to "defend", "protect", "guard", "uphold", and "sustain" our markets for wood? In a personal career that has spanned only a little more than 15 years, every meeting of men interested in wood attended has resulted in discussions relating to the dwindling markets for wood. It is probably not an extremely rash statement to say that this is a common experience for every one interested in and employed by the wood industry, regardless of his age or span of experience.

The statistics that have been used to show the declining per capita consumption of wood and the equally disturbing gains of competitive materials are manifold. All of us have heard them time and time again. It is sufficient to say here that such statistics do exist and that they are factual. Neither the statistics nor the conditions creating them have been improved through mere repetition. This is a situation much like the old saw that everybody complains about the weather, but nobody does much about it. The problem of our diminishing wood markets, however, is not quite so complex nor so insolvable. True, most of us complain about our wood markets, but something can be done to improve the situation and, what is most encouraging, some few are doing something about it.

Wood Has Been Cheap and Abundant

In our history, wood has been regarded as a material of great abundance. Further, its adaptability and versatility have resulted in its being utilized as a nearly universal manufacturing and construction material. We have used wood almost indiscriminately; in many instances not because it was particularly well suited for a specific application, but rather because it was available, inexpensive, adaptable, and perhaps because it was also attractive.

Our approach to selling wood has progressed in much the same way. If we have tried to do any selling at all, we have stressed most its availability and its cheapness. In that respect, we have done a good job. All too frequently today, the public does consider a wood product to be "cheap", in the unfavorable connotation of the word, and that the product may be undesirable because it is made from wood.

Wood: Competitor's Yardstick

How do our competitors sell their products? In the first place, they know their product, be it metal or plastic. They know its virtues and shortcomings. They know where it can serve and serve well, and, to a large extent, they exploit it in those fields where it is best suited. They make every effort to let the public know the outstanding features of their product and rarely, either by implication or by example, will they fail to compare its performance with that of wood. Whether we realize it or not, wood has become a public standard— a means of assessing the worth of another material. Unfortunately, wood is a standard not because of its excellence, but largely because of its failures. How many products made from competitive materials can you list that have been advertised and promoted into lucrative businesses because "they will not rot"; "they will not burn"; "they will not shrink nor swell"; "they do not require painting or finishing"; "they do not have troublesome joints"; and so

[1] Presented at Session V, Wood Preservation, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

The Author: C. H. Hoffman received a BSF from Pennsylvania State University. He was a technologist with Fairchild Aircraft and Assistant Laboratory Manager and Technical Representative with Timber Engineering Co. before he assumed his present position in 1955.

on? The list is almost interminable. Yet, without question, we who know a little about wood can point out instances where wood is superior, or can be made superior, to the competitive material that is replacing wood in a specific market. Nevertheless, wood, the raw material upon which we and so many others depend upon for our livelihoods, has been and is still being supplanted by other materials, which all too frequently are not fundamentally superior. However, those materials are better applied, better exploited, better fabricated, better known by the producer and seller, and better merchandised than we have done with wood.

As an industry, we are primarily at fault and we cannot blame our competitors for exploiting our shortsightedness, our apathy, our aversion to change, and our very real and inexcusable ignorance of our product. Much of this has been said again and again in past years in one way or another, but the passage of time has not corrected the situation nor even alleviated it to any degree. Probably one of the most apt explanations for the situation the wood industry finds itself in today was given several years ago by C. D. Dosker, President of Gamble Bros., Inc. Mr. Dosker explained then that our industry was suffering from "Grandpappy-itus". It is only a little less true today.

Now, what can we do to "preserve" markets for wood? There are many things we can do, just as there are many things we should stop doing, if we are to keep our markets for wood and wood products.

Past Practices Inadequate

Without question, the abundance of wood, its ready availability, its versatility, and its low raw cost are real and valuable selling assets. But they alone are not nearly adequate to sell wood nor to maintain its markets. We cannot continue to sell wood on the basis of its abundance and low cost unless we are willing to be content with only that part of the market which these features will satisfy. We cannot continue to sell defensively and not expect producers of competitive materials to avail themselves of the opportunity to exploit their products at the expense of wood. We cannot continue to produce only wood as a product and expect it to compete with other materials that can be and are more refined, more modified, and better engineered for specific purposes.

Fig. 2.—Impreg filter press plates like this last three or more times longer than untreated wood plates of naturally durable species.

Fig. 1.—Imaginative design plus pressure-creosoted poles resulted in this modern ski lodge at Greek Peak, New York.

Improved Products From Lumber Procedures

On the constructive side, the fundamental but outmoded practice of producing only boards and lumber at the sawmills can be substantially improved. Some progressive mills in this country are still producing lumber as their primary product but, in addition, they are also producing specialty stock for specific purposes and even completed or semi-completed products at their mill sites. They are making wood available in a form that is more readily usable—they are putting a little more effort into serving their customers and exercising a little more care to make certain that the wood satisfactorily meets the individual customer's requirements.

Koppers Co. makes use of this type of service. Certain of our impregnated products require wood of definite sizes and quality. Only by being able to purchase this material in the form we require it can we produce these products and sell them on a competitive basis. If we were forced to purchase lumber by grade, cut out the material we can use, and add those obvious costs to our products, we should be in a very poor competitive position.

We are producing impreg from which we fabricate such items as filter-press plates and frames and Moore vacuum filter leaves for use in acid services. These products require wood of exceptional quality and specific sizes that cannot be supplied under any existing lumber grades. Consequently, we prepared our own rather simple quality and size specification, and a progressive Southern pine mill is supplying us with material that perfectly satisfies our particular requirements. With this wood, we are able to produce filter components that give three or more times as much service as untreated wood, but that cost only about half as much as competitive metal and plastic units, which are poised to invade this market.

If we stop to consider the hardwood dimension business, we realize that here is an entire industry that is founded on service to industry—supplying wood in the size, shape, and quality required by the customer. Why is it, with the exception of a few outstanding lumber companies, that this type of service is not a normal practice? Would not the fabricator of any product be more inclined to use wood if it were available to him in the size, shape, and quality best suited to meet his requirements?

Well-Designed Wood Products for Specific Applications

As a second consideration, we must strive to capitalize on the known virtues of wood—its beauty, warmth, strength, workability, and so on to

Fig. 3.—The crossing panel, railroad ties, highway posts, telegraph pole, and floodlight poles are all creosoted to make wood serve more satisfactorily.

Fig. 4.—The mortgage on this Florida home is secure in spite of the high termite hazard because all the lumber was treated with preservative.

name a few of the many. But, in addition, we must develop more products that really exploit the best properties of wood and take advantage of its inherently good qualities, while minimizing the effects of its shortcomings. We need more good, sound development work of the type that led to such products as plywood, laminated arches, trussed rafters, and timber trusses. Each of these products, in its way, utilizes wood to its best advantage and, with proper processing, "up grades" wood to make it more desirable and more useful for specific purposes. Each of these products annually represents the processing and sale of substantial volumes of wood. While it is true that each of these was developed to satisfy a definite need for such products, it is also true that a lot of additional work has been done to sell these products and to insure their continued sales.

The development of the plywood industry has been phenomenal. It now produces the staggering volume of approximately 6,385 million square feet of all classes of plywood. This is a well-designed, well-made, and well-engineered product, but producers have not waited for it to sell itself nor apathetically waited for its myriad of competitors to replace plywood in the market. Individually, and through their associations, they have practiced aggressive sales campaigns, provided technical services, and assured quality control.

The segment of industry that produces laminated construction members is relatively new, but in its few years as a recognized business, there producers have progressed to the stage of supplying products valued at $224 million in 1954, an increase of 117 per cent over 1947 production. Again, these are well-designed and well-fabricated products that are also frequently used for their architectural "eye appeal". These producers have not been content with only producing a good product. On the contrary, The American Institute of Timber Construction and its affiliates have been selling aggressively and competitively, and providing the purchasers with excellent technical, quality control, and engineering services.

The tremendous volume of wood that has been utilized in the construction of engineered timber trusses and trussed rafters has been made possible in this country largely through the efforts of the Timber Engineering Company. The recent Silver Anniversary Report issued by Teco states that more than 100,000 carloads of lumber valued at $110,000,000 has been used for this type of construction. Significantly, it is also reported that $1,000,000 was spent for designing, engineering, and research to develop this type of construction, and that $5,000,000 was spent for lumber trade promotion to sell it.

Minimize or Eliminate Limiting Characteristics of Wood

As a third consideration, we should make every effort to improve those characteristics of wood which seriously limit its serviceability. As our competitors so cheerfully make haste to point out: wood does rot; wood is attacked by insects; wood does burn; wood does shrink and swell and check and split; wood is subject to attack by acids and alkalis; wood does require painting or other surface protection.

Anything that can be done to change the nature of wood so that these faults are eliminated or minimized must certainly improve the marketability of wood or a wood product. Surely, a wood product developed from wood without these objectionable characteristics can be better designed, better engineered, and will give better service in a wider range of applications than has been possible in the past. Happily, we are learning that we can improve the properties of wood by processing it properly.

The history of the use of preservatives has proven that wood can be used in severe exposures with little fear of destruction by decay-producing fungi or termites. In spite of this, the per unit use of wood in home building has steadily decreased. Masonry and concrete have largely replaced wood in home construction in areas of severe exposure conditions, primarily because unprotected wood has failed and continues to fail in this type of service. Service records accumulated by the American Wood Preservers Institute show that the use of a minimum amount of preservatively treated lumber in homes in these critical areas has freed owners from the worry of loss from decay and termite damage.

At one time, the future of the wood millwork business appeared doomed. The supply of the relatively durable eastern white pine normally used for window sash was virtually exhausted and the available species of comparable quality were not so durable. A simple, short dip of the window assemblies in a water-repellent solution of pentachlorophenol has provided an even more durable wood product, and, what is more important, has enabled the wood millwork industry to compete favorably with fabricators of competitive materials.

Probably one of the finest achievements and greatest gains achieved with wood in the construction field in recent years has been the introduction and development of the pole-frame type of construction. This has been possible only because of the confidence in the durability of preservatively treated poles that has been created through years of authenticated service. No accurate data exists regarding the wood, apart from the poles, that has

been used to complete these structures, but the sale of poles for this purpose, which represent only about 10 per cent of the total value of materials used in these buildings, has developed into quite a nice business.

Prejudice against wood, and laws and building codes restricting the use of wood in construction, have developed because wood burns. The fact that other types of construction may collapse simply because of heat has not altered this fact. Those materials don't burn, while wood does, and that fact has been exploited. Slowly we have developed fire retardants that very effectively inhibit the burning of wood. However, the prejudice against wood has reached the stage that laws, codes, insurance regulations, and public opinion make it extremly difficult to promote even wood that won't burn. Further, we have no perfect fire retardant. Most of them have objectionable features such as reducing the strength of wood, or discoloring the wood, or causing the wood to be hygroscopic.

An improved fire-retardant treatment for wood that will not detract from its utility and that, preferably, will improve some of wood's other limiting characteristics would be a definite aid to our problem of expanding the market for wood. Our research people have recently come up with one that has considerable promise. In the first place, it is a good, leach-resistant fire retadant. As additional bonuses, it imparts some degree of stability to wood and some decay resistance. Further, it does not appreciably discolor wood, it does not adversely affect the strength of wood, and it does not make wood hygroscopic. We are now working with this treatment on a pilot plant scale, and if these studies prove as encouraging as the laboratory work, we are confident this treatment will open new markets for the wood products of today.

The problems that develop because wood shrinks and swells are unlimited and have existed as long as wood has been used. We have known for a good many years that this objectionable characteristic can be minimized by any one of several treatments. Yet we did not promote this form of wood and permitted it to remain a laboratory curiosity. It required the good efforts of a specialized user of wood from a completely different industry to spearhead market development for this product. The Ford Motor Company has certainly performed a real service for the wood industry by proving the value of impreg, thereby creating a new industry to produce an up-graded, improved form of wood. Granted, this is a form of wood that is expensive to produce and its sale is now restricted to a rather limited, specialized market. Nevertheless, we are convinced that this is only a good beginning and additional markets will be developed. Also, improved practices and other methods of treatment can lower the cost of dimensionally stabilized wood to further broaden the markets.

In addition to its dimensional stability, the present form of impreg has other desirable properties that open other markets for this form of upgraded and improved wood. Properly made impreg exhibits an excellent ability to withstand the attack of destructive chemicals. It has been proven that phenol impreg can perform from three to six times longer than naturally resistant species of wood when exposed to acids. Another impreg made with furfural alcohol, gives excellent service in both acid and caustic services.

The best and most economical treatments for wood have not yet been developed. Although our present treatments are making wood more valuable, more versatile, and more serviceable in a wider range of practical applications, undoubtedly there are better and more economical preservative, fire retardant and stabilizing treatments still to be discovered and developed. Moreover, there may be more universal treatments that will materially improve wood in several respects.

Ultimately, it is not inconceivable that one treatment should render wood resistant to decay, termites, fire, and conditions that cause it to shrink or swell. Research and development people are working hard, often to the limits of their ability and finances, to produce better treatments for wood. We sincerely believe there are good markets for improved forms of wood. We believe that wood is fundamentally a good, serviceable material and that broader, more lucrative markets for it can be developed if it is properly processed to take advantage of its inherently good properties and to minimize or eliminate its poorer properties. We belive this can be done and are doing our very best to reach this goal.

Better Utilization to Reduce Basic Cost of Wood

Much earlier in this paper, inexpensiveness of wood was discussed. Today, this is only a relative term and if we are realistic about it, wood is not really a cheap material. We who are involved with the processing and further modification of wood are finding that it can be a rather expensive raw material. The cost of lumber, to a large degree, does limit the amount of expense, in the form of modification, processing, refinement, and fabrication that can be added to the cost of a wood product. Obviously, in spite of everything that may eventually be done to improve wood and wood products, the final selling price of the item will largely control its marketability because it still must be sold competitively.

Great advances have been made by the logging and sawmilling segments of the wood industry in devising better, faster, and more economical methods of logging timber and making lumber. However, rising production costs, higher stumpage prices, and perhaps higher selling costs have offset the benefits of these mechanical improvements, and the price of lumber has continued to rise through the years.

Much too great a percentage of the tree is left to rot in the woods or is conveyed to burners or some other means of disposal. Researchers at the U. S. Forest Products Laboratory, and others dedicated to wood research, have repeatedly told us that this wasted wood represents a wealth of renewable raw materials that are suitable for many purposes. They have worked well and diligently, with little encouragement, to show us what can be done with this so-called waste. Imagine what it would mean to the cost of our wood products and their ultimate marketability if this wasted material were to be profitably utilized. It might be easier for us to speculate on the prices we should have to pay for meat if that industry produced only steaks, roasts, and chops, and discarded the rest of the animal. Essentially, that is exactly what we do in the wood industry.

Conclusions

In summary, we can preserve, and even substantially broaden, our present markets for wood. To do so, however, will require the best efforts of all phases of the wood industry—the producers, the processors, the sellers, the researchers and the developers; all have important parts to perform. None of the factors contributing to the decline of our market for wood is insurmountable if we upgrade our products to the degree that is possible. The few examples cited to show what can be done are not conclusive, but without doubt, they do point the way towards improving our markets. There is a long way to go, admittedly, but we can do much to improve our position by developing:

1. Better and more aggressive educational and sales techniques to exploit the superior properties of wood.

2. Better practices to make wood available to processors in the size, shape, and quality best suited for their particular purposes.

3. Better processes and techniques for producing more products that utilize wood to its best advantage and that are designed for specific purposes.

4. Better processes and techniques to fundamentally improve wood and eliminate or minimize its poorer characteristics.

5. Better processes to utilize the so-called wood waste and thereby reduce the cost of wood, the primary raw product of our industry.

Discussion

R. V. W. Vaughn (L. Vaughn Co.): What method of treatment is used with Koppers Co. fire-retardant preservative?

Mr. Hoffman: We prefer a pressure treatment. A dip method can possibly be used, but it is time-consuming and somewhat unpredictable.

Mr. Vaughn: Does this retardant have possibilities to withstand the Underwriters present standards?

Mr. Hoffman: This is not known, but we hope so. We plan to make this deterimnation as our development work progresses.

Mr. Vaughn: What type of carrier is used with this preservative? If water is used, is it possible to substitute a petroleum product so that the stability of the wood products would not be upset? If petroleum solution is permissible, could mineral spirits be used?

Mr. Hoffman: Water is used as the carrier.

C. B. Hemming (U. S. Plywood Corp.): Does furfural give the same dimensional stability as phenol?

Mr. Hoffman: Yes, our data show it to be the equal of phenol, but is slightly more expensive.

A. R. Tegge (Quartermaster Food and Container Institute): Is any dip or soak method (and material) effective for fire-retardant treatment of 3-ply, ¼-inch-thick, medium-density plywood?

A. B. Bishop (N. Y. State College of Forestry): AWPA has standard C–20 for the fire-retardant treatment of plywood by pressure processes. Treatment is difficult because of the glue lines; solution must go chiefly through the end grain. I do not believe you can get satisfactory treatment of 3-ply plywood by a dip treatment or by a short soaking period.

J. P. Foley (Liberty Lumber Co.): If I understand you correctly, is it fair to state categorically that the lumber industry is doing little or nothing in the way of research and development to promote the sale of its products? Particularly in view of the outstanding job in research that has been accomplished by the Weyerhaeuser Timber Co., Crown–Zellerbach, Pacific Lumber Co., Evans Products Co., and many others?

Mr. Hoffman: You may have misunderstood me. The problem is not insurmountable, and, as I have stated, some people are doing a good job.

Mr. Bishop: Much more should be done for the good of the industry.

HISTORY AND DEVELOPMENT OF Wood Preservation for Millwork[1]

O. C. Lance
Secretary–Manager, National Woodwork Mfr's Assoc., Chicago, Illinois

The NWMA initiated its "Seal of Approval" program in 1938. Today, over 85% of all stock sash is treated with water repellent and preservative, and carries the NWMA Seal.

Andersen Windowalls about to receive a 3-minute penta dip.

THIS IS A SUCCESS STORY. It is the story of how research and the cooperation of several interested industries plus wise promotion efforts turned the tide of competitive products and kept wood windows and other millwork items in a prominent position in the building industry. But the story goes further than that, for out of the work reported herein sprang the basis for other work by other branches of the wood industry that has helped and will continue to help them com-

[1] Presented by Ira Hatfield at Session V, Wood Preservation, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

The Author: Ormie Lance holds an LLB degree from Northwestern College of Law. He was secretary of the North-Western Lumbermans Association from 1929 to 1942, and, after a tour of military duty, accepted his present position in 1946.

Fig. 1.—Conveyorized system used with an elevator for dip-treating millwork at the factory.

Fig. 2.—Here a load of doors is being lifted from the treating solution by the elevator.

pete more ably against competitive products.

The story starts back in the early 1930's. Although wood had always served admirably as a construction material and had amply demonstrated its durability along with other quality features, it was recognized that, under certain use conditions where either design was faulty or moisture conditions were unfavorable, decay and "sticking" of wood windows did occasionally occur. Manufacturers of windows and sash made of competitive materials were playing on these factors to promote their products. They failed to point out, of course, that steel corrodes, that aluminum pits, that both metals have far lower insulating value than wood, and that they too require proper maintenance for satisfactory performance.

Problems Were Recognized Early

The millwork producers were not asleep to the need of overcoming the problems connected with the use of wood under conditions of high humidity or faulty design. In fact, where possible, improved design was employed and some attention was being given to the use of chemical treatments then available. The chief colorless, oil-soluble chemicals obtainable at that time were beta naphthol and some of the lower chlorinated phenols.

The story that follows tells how the various industry and research groups interested in wood utilization were organized into a working unit to solve scientifically the problems that were of mutual interest. The groups involved consisted of:

The Western Pine Association, concerned with the production and proper utilization of western pine lumber.

The National Door Manufacturers Association, an association of millwork producers concerned primarily with the manufacture and sale of wood windows, sash, and doors.

The U. S. Forest Products Laboratory.

Specific companies producing millwork.

Millwork jobbers and dealers.

Segments of the chemical industry, especially those interested in the development and sale of wood preservatives.

Several universities directly interested in forest products research.

The "Seal Of Approval" Was Inaugurated In 1938

In the early work reported by the Western Pine Association, Hubert (10) [2] said "One of several projects conducted in the Research Laboratory of the Western Pine Association in 1935 was the study of the control of stain and decay in finished wood products, such as sash, doors, frames, porch columns and general millwork, which are ordinarily exposed to considerable moisture during service". When the preliminary results of that study were published in 1936 (19), the value of certain chlorinated phenol formulations was given. The National Door Manufacturers Association (the name of which was later changed to the National Woodwork Manufacturers Association, and for brevity of reference will hereafter be simply designated NWMA), desiring to take full advantage of these findings, appointed a committee to study the question as to how these results could be put to use by the millwork industry. This Preservative Standards Committee, as it was called, had its first meeting in the fall of 1936. Working closely with millwork manufacturers, jobbers, the chemical industry in position to furnish wood preservatives, and public and private research laboratories, the committee proposed a "Code of Minimum Standards for Millwork Preservatives" and set up a "Seal of Approval" program. This program featured the following objectives: a) To counteract the propaganda of metal competitors who were making capital of the fact that wood rots, b) to stimulate the preservative treatment of millwork, c) to provide a method of identifying treated woodwork through the use of the NWMA seal, d) to establish minimum standards for treating solutions, and e) to establish minimum standards for the method of treatment. The first printed announcement of this program was made in November, 1938. Very shortly thereafter, seven applications for license to use the NWMA seal were received and approved. This approval meant that the millwork produced by those licensees, if treated according to the NWMA standards, could bear the "Seal of Approval" of the Association (Fig. 4).

Advisory Committee Was Set Up For Technical Council

By 1940, a total of 45 licenses to use the seal had been issued, and it is estimated that in 1957 over 85 per cent of all stock sash was treated according to this standard.

Almost as soon as this program was launched, the members of NWMA's Preservative Standards Committee realized that they needed technical advice and counsel, and proposed that an Advisory Committee be organized to consider methods of studying various preservative solutions and their efficiencies, and methods for testing all features embodied in the preservative program of the millwork industry. To that end, various segments of the industries involved were invited to send

[2] Numbers in parentheses refer to the Literature Cited at the end of this article.

technical representatives to an organizational meeting at the U. S. Forest Products Laboratory in May, 1938. Eleven people attended this meeting and took the following action: a) Adopted a policy of inviting other interested persons actually engaged in laboratory work on millwork preservatives to become members of the committee, and b) recommended a code of minimum standards for adoption by the NWMA relating to toxicity, leaching, and volatilization of treating solutions. This was a revision of the code originally adopted as a tentative standard by NWMA's Preservative Standards Committee in April of 1937 and February and March of 1938. At this meeting, the committee also studied a tentative draft of a "Method of Testing Oil Soluble Wood Preservatives Using Wood Blocks Uniformly Impregnated" as submitted by Dr. E. E. Hubert. The committee also recommended that the Association could safely proceed to approve for use by its licensees treating solutions that contained a minimum of 5 per cent by weight of pentachlorophenol, of 2-chloroorthophenylphenol or of tetrachlorophenol, or 5 per cent of any mixture thereof. Thus was organized NWMA's Preservative Standards Advisory Committee, which has continued to function effectively since that original organization meeting in May, 1938.

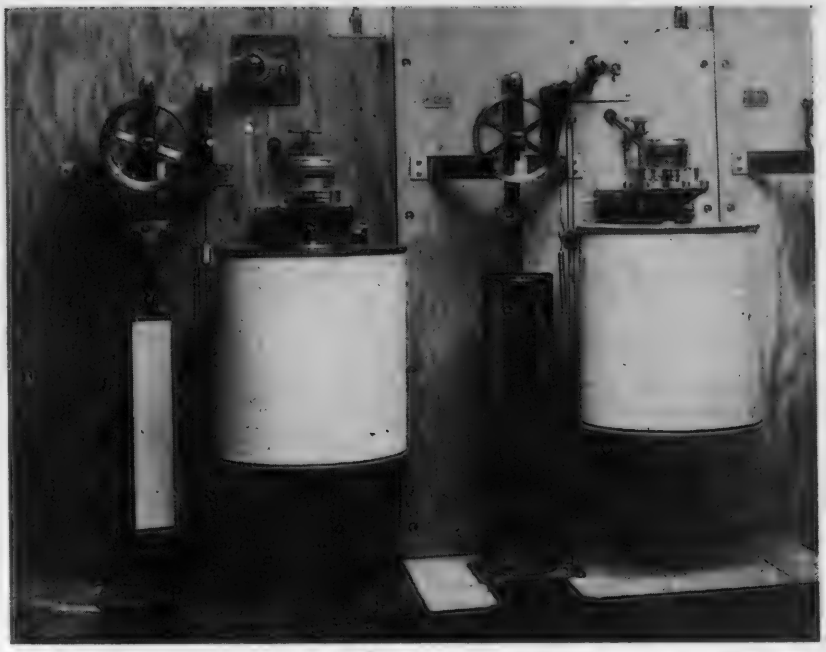

Fig. 3.—Swellograph units, the one on the right with the water cylinder in place, and the one on the left with the cylinder removed to show the specimen held in place.

Program Had To Be Sold

The first steps taken in this "success story" involved a) the realization of the need for action to stimulate progress, b) the promotion of the program of two Associations interested in the use of wood, c) the enlistment of the cooperation of the millwork producers, and d) the stimulation of the technically trained people in chemical and wood technology laboratories to find answers to the problems involved.

Next came promotional efforts. The meaning of the minimum standards and seal of approval program was printed in special announcements and, as the first step in the promotional campaign, these announcements were sent to 36,000 architects, building contractors, woodwork jobbers, retail lumber dealers, local housing authorities, and Federal and State specification agencies. Also released were four folders entitled "Wood Accepts the Challange", "Out of the Laboratory Comes an Even Longer Life for Wood", "Coming Generations Will See the Wood Just as Sound—the Detail as Crisp and Distinct as it is Today" and "Progress and Tradition Favor Wood".

The NWMA Toxic Water-Repellent Standard

Once a standard for testing millwork preservatives was approved [3] the Preservative Standards Advisory Committee (PSAC) undertook the task of developing standards for a water-repellent preservative solution. Subcommittees were needed to develop nomenclature to describe different qualities imparted to or modified by the treatments (1), and to study paintability, puttyability, sludging characteristics, and other problems involved in putting the accomplishments on a good scientific basis. Furthermore, the NWMA realized that an impartial laboratory should be utilized to evaluate products proposed for use under the Seal of Approval program. To that end, the NWMA engaged the services of the Wood Products Laboratory of the University of Michigan, which thereupon became the official testing agency for the NWMA.

Unfortunately, in reporting research progress, the final conclusions that may be expressed in a few words do not indicate the magnitude of the man-hours required to accomplish that progress. Reams of correspondence between committee members and the NWMA followed by relatively frequent meetings of the PSAC finally resulted in the development of a water-repellent test method. [4] After considering many methods of testing water-repellent efficiencies, eight laboratories studying the efficiency of five solutions, submitted under code, were able to determine the two good ones and the three unsatisfactory ones. These results led to the final adoption of the official test method and to the addition of water-repellent treatment to the NWMA Seal of Approval program in June of 1948 (Fig. 5).

[3] NWMA 1953. NWMA-M-1-53, Standard NWMA methods for testing the preservative property of oil-soluble wood preservatives by using wood specimens uniformly impregnated.

Scope Of The Standard

When the NWMA announced the Standard for Water Repellent Preservatives for Woodwork in 1950 (revisions were made in April 1951 and July 1953), the scope of the standard was as follows:

[4] NWMA 1955. NWMA-M-2-55, Standard NWMA swellograph method for testing the water repellent value of treating solutions.

Fig. 4.—Seal of Approval grade mark for millwork treated according to NWMA minimum standards.

Fig. 5.—Seal of Approval grade mark for treatment that combines water repellency with preservation.

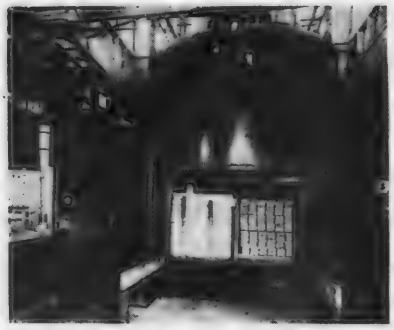

Fig. 6.—Vacuum Sealer Unit for treating millwork with a water-repellent preservative solution.

a. General properties.
   1. The preservative solution shall be a non-aqueous solution made essentially from hydrocarbons and oil-soluble chemicals. It shall contain no more than a trace of water.
   2. It shall not discolor wood unfavorably; shall not have an objectionable odor; shall be non-injurious to man when properly handled; shall not be deleterious to the serviceability of putty, paint or varnish; and shall be relatively non-corrosive to common metals.
   3. The toxic chemical shall be completely soluble at working temperature in the solvent used, and the preservative solution shall contain no sludge that will adversely affect the appearance of the treated product or the effectiveness of the treatment.
   4. The liquids carrying the toxic chemicals and other ingredients shall provide effective distribution of the toxicant in the wood.
   5. The flash point of the treating solution shall be above 100° F. when tested by the Tagliabue closed cup method.

b. Formulas. A ready-to-use solution of water-repellent preservative, as anticipated for use at a woodworking plant, shall be submitted by the woodworking plant to the NWMA Committee on Preservative Treatment for their approval before adopting for use at the woodworking plant and before the NWMA Seal of Approval can be used. When the formulation as the ready-to-use formulation is approved for use by a woodworking plant by the NWMA Committee on Preservative Treatment, it shall be used without change until a proposed change is approved by the NWMA Committee on Preservative Treatment.

c. Toxicity.
   1. For a solution to be acceptable to NWMA for the use of the water repellent Seal of Approval, the concentration of the toxicant in the solution shall bear at least as high a ratio to its threshold[5] concentration as 5 per cent by weight of pentachlorophenol bears to its threshold concentration when tested for effectiveness against decay by the standard NWMA Wood Block Method. (NWMA–M–1–53)
   2. The NWMA Committee on Preservative Treatment reserves the right to require toxicity data in addition to that stipulated in the three preceding paragraphs above, if the toxicant is new and satisfactory technical data relative thereto are not available.

d. Water repellency. The water repellency of the preservative when tested by the NWMA Water Repellent Test Method (NWMA–M–2–55) shall not be less than 60 per cent after 30 minutes of imersion of the test wafer in the swellograph. Any preservative which shows an effectiveness of less than 50 per cent shall not, however, be rejected until it shall have been retested by the NWMA Water Repellent Test Method. If the retest shows water repellency less than 60 per cent, the preservative shall be considered as having failed to pass the test.

e. Penetration. The treated woodwork shall show an average longitudinal or end penetration of not less than 1½ inches beyond any point of contact between abutting members. The woodwork must be treated for a sufficient length of time as prescribed in rules and regulations of the association to give penetration above stated.

   Periodic inspection of the depth of penetration as it correlates with the treatment cycle shall be made at each fatcory.

Since the adoption of standard nomenclature and test methods for testing preservatives and water repellents, the PSAC has turned to perfecting the existing methods to give them added value and meaning, and to considering other methods that would help insure progress in this phase of wood preservation. The PSAC has also kept abreast of the work of other segments of the wood preservation industry to correlate, augment, or otherwise aid the total wood preservation program.

To illustrate the progressive attitude of those working closely with the millwork industry on test methods, numerous methods for testing the moisture-excluding properties of water repellents have been devised. Each method seemed to show good points or weaknesses of commercial products. Among the tests employed were the curl test (14), the Western Pine Association swellograph test (7), the original NDMA test (7), what is known as the run-off test, and a test designated as the spray test, to name only a few. As the number of test methods increased, the question arose as to whether any one or more of them could be eliminated because they did not give data already obtainable from some other method. Furthermore, the NWMA had selected the swellograph test as its standard test method, and wanted to know if it should continue it as a standard or replace or augment it. To that end a sponsored research project was initiated by the NWMA early in 1956 at the U. S. Forest Products Laboratory to compare the results of selected test methods and to correlate those results with field performance tests. This work is still in progress.[6]

Fig. 7.—Dri-Vac unit for treating millwork.

Out of the original work of these NWMA committees came the commercial practice of immersing the fabricated millwork products for a minimum of 3 minutes. It was demonstrated that immersion beyond that length of time did not give sufficient additional penetration to warrant the slowing down of production that would result.

Manufacturers of treating equipment also became interested in this phase of wood preservation, and various adaptations of immersion equipment as well as new methods of treating were proposed. One such method was the "vacuum method". At the PSAC meeting in October of 1952, it was proposed that the vacuum method be approved as a treating method whenever the user of the method would certify that penetration and retention by the vacuum method was equal to that obtained by the 3-minute immersion method. Two types of vacuum equipment are used: the "elevator and dome" type (3), and a rectangular tank (20).

The success of such a plan as has been described above can be measured in two ways, namely: what has been accomplished and what the committees have before them for further study. Some of the accomplishments of this project have been enumerated; others are actual by-products. In the latter category belong, in no small way, the setting up of government standards for wood treatment such as TT–W–572 and TT–W–571; the incentive to devise better test methods for studying the depth of penetration of "colorless" preservatives into wood; and the stimulation to improve the technology of preservative testing.

[5] The threshold concentration is to be interpreted as meaning the lowest concentration of the toxicant in the treating solution at which freedom from attack from the NWMA specified decay test fungus takes place.

[6] It is hoped the research mentioned here can be presented to the Society in one or more separate papers.

Fig. 8.—Treated and untreated window frames were exposed to determine effectiveness of water-repellent preservatives. Although both were well painted, untreated frames varied from 8 to 24 per cent in moisture content and stuck badly; treated frames varied from 8 to 13 per cent, did not stick.

Fig. 9.—These windows (left, treated with water-repellent preservative, right, untreated) were exposed in a humidity room. Blue stain developed on joints of the untreated frame, and caused subsequent stain on the window.

The Preservative Standards Committee and the Preservative Standards Advisory Committee of the NWMA have before them such subjects as the possibility of writing specifications for the pressure treatment of millwork; the perfection of visual methods for showing that treated wood has been treated without interfering with the natural color of the wood or its finishability; the study of how to improve the quality of coatings on treated millwork; and the correlation of NWMA test methods with methods used by other segments of the wood-preserving industry.

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Discussion

H. Schwartz (Ottawa Forest Products Laboratory): Canada is going through some of the same phases of which you spoke, and I have several questions. In the U. S., has an assessment been made of the decay that occurs in untreated millwork?

James Nolan (National Woodwork Mfgrs. Assoc.): No records were kept, but it was quite evident there was a problem because of 1) complaints received on some installations, and 2) claims stated by competitive industries.

Mr. Schwartz: Is there any proof of the value of a 3-minute dip over shorter dips?

Mr. Hatfield: The absorption curve for ponderosa and sugar pine (the species commonly used in making stock sash) goes up and then levels off at between 2 and 3 minutes. It is desirable to get maximum treatment without disturbing the manufacturing flow of the wood items through the plant. U. S. manufacturers have found that this cycle (3-minute immersion) can be worked into their process cycles by proper planning.

Mr. Schwartz: Is there any information on the advisability of using a pigmented dip?

Mr. Hatfield: This problem has come up because of the advantage of a prime coat. Unfortunately, a sealer coat upsets the penetration of preservative into wood. I do not know of anyone who has solved the problems involved.

John Reno (Pacific Lumber Co.): I would like to comment on the 3-minute versus the 30-second dip. We do know that the wood picks up the most of the preservative in the first 30 seconds, but we also know that most manufacturers are in a hurry and specifying a 3-minute standard does assure at least a 30-second dip. In regard to the pigmented dip, it must be said that mill priming is very dangerous. One other reason beside penetration difficulties is that a prime coat should be followed by second or third coats in a couple of weeks. This is not always possible.

EQUIPMENT AND COSTS FOR

Profitable Charcoal Briquetting[1]

P. D. HAIGH
Vice-President, Komarek–Greaves & Co., Chicago, Illinois

Success of a briquetting operation depends on quality of charcoal, sound choice of equipment, and proper binder. Hardwoods are standard, as is starch binder. Initial total investment for a one ton per hour plant is $200,000.

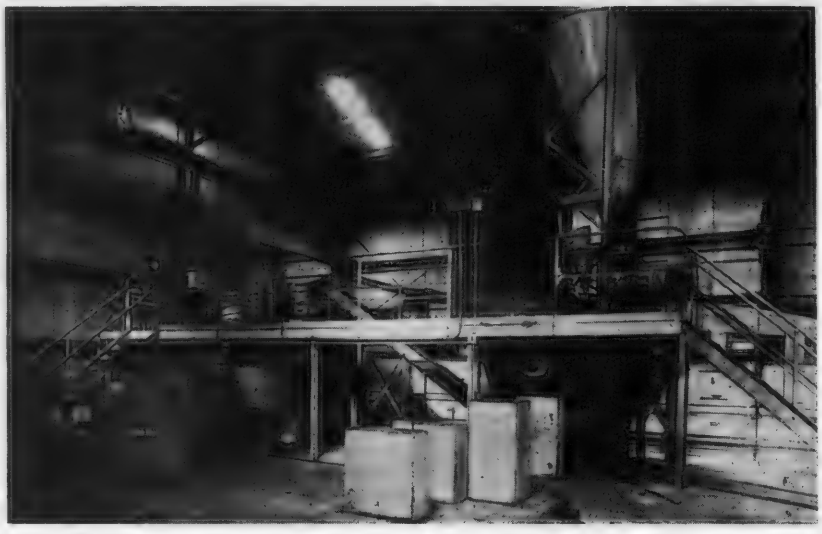

Fig. 1.—Charcoal briquetting unit. The charcoal is fluxed in the vertical unit at right, goes up the inclined conveyer (center) into the briquet press (left). Capacity of the unit is one ton per hour. In the foreground are foundations for a future unit.

ORIGINALLY, THE BRIQUETTING of charcoal provided a means to turn wood waste into a salable commodity, which was used mainly by hotels, restaurants, and Pullman diners for the grilling of food.

This method of cooking advertized itself, and about five years ago a new market developed that has been growing each year. The American public decided that cooking out of doors is a pleasurable experience, and adopted charcoal briquets as the heat source, because briquet packages are clean, fires are easily lighted, and the smokeless heat is ideal for grilling and other types of cooking.

To meet this growing demand, charcoal briquet plants have come into existence from California to Maine and Florida to Canada. Some companies had only a briquet press and started into business without much thought as to the ultimate excessive cost of the operation, while others are reaping the benefits of well-designed plants.

No text books are published on the subject, but the following outline is made from actual commercial briquetting experience, and the plants described contain a minimum of equipment. Many factors enter into the building of a plant, and these will be treated under separate headings starting with the most important of all.

[1] Presented at Session XV, Chemical Utilization (2), FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

Selection of Charcoal

Most of the successful plants briquet hardwood charcoal. Therefore, the quantity of hardwood charcoal available is of prime importance in determing the plant capacity.

The charcoal must be clean to eliminate excessive abrasion of the plant equipment. If the charcoal is not clean, it can be screened to remove objectionable foreign material.

The charcoal must be reasonably dry, because in spite of the fact that water is used in the binder, and indefinite water ratio can upset the entire operation and result in wet briquets sticking to the press rolls and dry briquets with low ultimate strength.

Comparison of Equipment for Large and Small Plants

Standard capacities are one ton and 3-1/2 tons per hour. The items of equipment are basically the same for each capacity.

The 3-1/2 ton unit consists of large, heavy equipment that requires mechanical handling for all parts when changes are made and parts are installed. The one ton unit consists of proportionately lighter equipment, and most changes can be made manually.

Equipment for a Small Plant

Standard equipment for a one ton per hour charcoal briquet plant is listed below.

Item 1 Screw conveyor from charcoal hopper to hammer mill. 3 hp motor drive.

Item 2 Hammer mill with hopper to grind charcoal to minus 1/8-inch screen size. 15 hp motor drive.

Item 3 Crushed charcoal conveyor to convey ground charcoal from hammer mill to surge hopper. 2 hp motor drive.

Item 4 Charcoal feeder with surge hopper to convey continuously the exact amount of charcoal required. 2 hp motor drive.

Item 5 Paddle mixer for preliminary mixing of charcoal and starch binder. This mixer is small and discharges directly into the vertical fluxer. 2 hp motor drive.

Item 6 Vertical fluxer for final mixing and fluxing of the charcoal and starch mixture. 25 hp motor drive.

Item 7 Charcoal mixture conveyor to convey mixture from vertical fluxer to briquet press. 2 hp motor drive.

Item 8 Briquet press with paddle feeder. The briquet press must be equipped with automatic feed gate to supply the exact amount of mixture to the briquetting rolls. 15 hp motor drive.

Item 9 Briquet discharge conveyor to convey briquets from briquet press to dryer. 1/3 hp motor drive.

Item 10 Syntron starch feeder for pregelatinized starch or starch pump for starch paste.

Item 11 Briquet dryer. There are many types of dryers, but the conventional type has a single, slow-moving conveyor to receive the wet briquets at one end and discharge the dry briquets at the opposite end. Total 40 hp motor drives.

Item 12 Bagging equipment. This type of equipment is generally recommended by the bag manufacturers, and varies to suit plant capacity. It must be fully automatic.

Item 13 Boiler A 30 hp, 15 psig boiler is required for process steam and plant heating.

Item 14 Building for two units is 60 feet wide and 120 feet long, with a 20-foot clear height.

Economy of a Small Plant

A standard, one ton per hour plant has space for two units.

The operating platform is supported from the floor, and a single overhead beam with chain falls will service the heavier parts of the briquet press and vertical fluxer. All other machinery repairs are made from the floor.

The same operating crew can handle one or two units. The merits of this arrangement are obvious, because there need be no layoff during the slack months.

The operating crew for each shift consists of eight men.

One general foreman
Two charcoal men
One briquet operator
One floor man
One bagger
Two warehouse men for stocking out or loading box cars and trucks.
A maintenance man is needed on the day shift to keep the plant in proper running order.

Selection of Binder

Various binders have been tested for the purpose of reducing costs. Wood tar is a good binder, but the briquets must be retorted to remove the binder. After the briquets are retorted, they are water resistant. Sulphite liquor is a good binder, but these briquets must also be retorted. The briquets are then water resistant, but there is a question of odor when they are burned.

Two types of starch are in common use. Pregelatinized starch is introduced in powder form, and water is then added to the mixture of charcoal and starch. Starch paste is made in cooking tanks and then pumped into the mixer. The most satisfactory binder is starch, and either pregelatinized starch or starch paste is equally effective.

Fig. 2.—Charcoal briquet dryer. The briquets come from the unit at the left (shown completely in Fig. 1), and travel through the dryer unit (center) to the discharge at the right. Capacity of this unit is one ton per hour.

Complete Operating Procedure

Charcoal is fed as received by means of a screw conveyor through a crusher and crushed to minus 1/8-inch screen size. The crushed charcoal is then elevated to a small surge bin. Large bins are to be avoided because of fire hazard.

The charcoal feeder continuously carries the required quantity of charcoal from the surge bin to the paddle mixer. About 5 per cent starch is added to the charcoal in the mixer.

The combination of charcoal and starch is thoroughly mixed and fluxed in the two-shaft vertical fluxer, and is then conveyed to the briquet press. The briquet press must be equipped with a feeder and variable feed gate to produce briquets of proper density.

A briquet belt conveyor carries the briquets from the press to the dryer, and loads them uniformly by means of a special loading device.

Drying charcoal briquets is an exacting task, and care must be taken to hold the temperature below the point of ignition. The source of heat can be an oil burner, steam coils, or waste heat. In any case, the hot air is mixed with fresh air and reduced to the proper drying temperature.

As a rule, the last section of the dryer cools the briquets, and they are then conveyed to a bagging bin. Briquets are weighed and bagged by means of automatic equipment, and are then conveyed to a warehouse for stocking and shipping.

Probable Investment and Operating Costs

Capital investment and operating cost figures for large plants are not available, but the mechanical equipment and motors for a 3-1/2 ton per hour unit cost about $200,000.

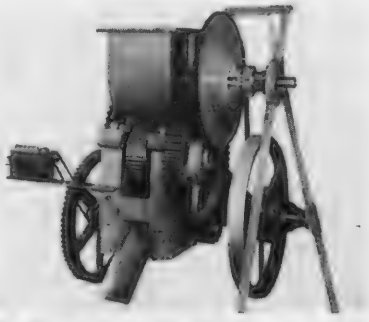

Fig. 3.—A charcoal briquet press; capacity of one ton per hour.

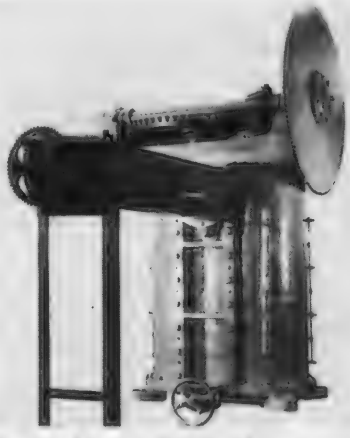

Fig. 4.—A two-shaft vertical fluxer; capacity of one ton per hour.

Initial total investment for a one ton per hour charcoal briquet plant complete with briquet building, office, boiler room, charcoal dock building, and briquet warehouse amounts to about $200,000.

A second one ton unit can be added for an over-all cost of about $80,000.

The operating cost for a one ton unit amounts to $25 per ton. This figure does not include the charcoal.

Production Statistics

There are 35 charcoal briquet plants operating in the United States. Total capacity of these plants is 50 tons per hour, and estimated production is 250,000 tons of charcoal briquets per year.

In conclusion, the briquetting of charcoal presents an exacting production problem that can be mastered by the use of well-designed plants, high-class operating personnel, and only the better grades of hardwood charcoal.

Discussion

Anon.: What type of hardwood is used to make the charcoal?

Mr. Haigh: All kinds of wood are used, although I imagine most people do not use saleable wood.

Ralph Peter (U. S. Forest Service): Is there a plant of less than 1 ton per hour available?

Mr. Haigh: No. This would be done by hand.

Anon.: Do railroads prefer briquetes, and if so, is it because of ease of handling?

Mr. Haigh: Railroads were the first to use briquetes. These were first made in Tennessee. I suppose this preference is at least in part because of ease of handling.

H. J. Knapp (Grenco, Inc.): Have you briquetted softwood charcoal?

Mr. Haigh: Yes, softwoods can be briquetted with some modifications.

Joseph Lupsha (Maine Forest Service: What is the principal reason for smoky briquetes?

Dr. J. A. Hall (U. S. Forest Products Laboratory): There may be a residue of volatiles in the briquetes.

Anon.: Has bark alone been used?

Paul Lane (Lake States Experiment Station): Much charcoal is made from slabs, which of course contain a high percentage of bark.

Wayne Meek (M & O Paper Co.): Raw, finely divided bark particles can be pelletized.

Russell C. Deckert (N. Y. State College of Forestry): In the production of briquetes, is it more economical to buy charcoal or product it yourself?

Mr. Haigh: It is best to produce your own charcoal.

Anon.: Carbonizing bark would give a higher ash content in the charcoal.

Dr. Hall: Ash content would vary widely with choice of bark.

Mr. Haigh: Charcoal made on sandy ground would contain much sand, which would cause trouble in briquetting.

FUNDAMENTAL TECHNIQUES INVOLVED IN Efficient Spray Finishing

J. F. McCaslin
Manager, Technical Services, The DeVilbiss Co., Toledo, Ohio

The efficient operation of a finishing room consists of proper controls, a logical method of spraying, and a perpetual training program. Without control, there can be no logical spray method, and without a perpetual training program it is nearly impossible to maintain an efficient finishing room.

THE EFFICIENT OPERATION of a finishing room consists of proper controls, a logical method of spraying, and a perpetual training program. Without control there can be no logical spray method, and without a perpetual training program it is nearly impossible to maintain an efficient finishing room.

A very important requisite of efficiency is economy. Waste from a spray operation is hidden in the spray booth until it can be carried out at night or over week ends. To recognize the inefficiency of a spray room, one must understand the effect of improper spray technique, high pressures, poor controls, and damaged or worn equipment. Variables should be eliminated. If each piece is to have the same finish as it comes off the production line, it should receive the same treatment.

Inefficient Practices

It is common for an operator to use more than a 50 per cent overlap of the spray pattern. This is tiring, slows production, creates dry film, and wastes material. An operator who uses too high a gun speed usually doesn't overlap 50 per cent of his pattern. At too high a rate, a number of passes are necessary to build up the film. High gun speed causes poor aiming and control, and results in loss of material.

Spray losses increase with gun distance as does the solvent loss. Solvent loss is generally corrected by either the addition of more solvent or use of slower solvent. The spray loss ends up in the spray booth.

Arcing the gun is a habit developed by most operators. It is not uncommon in arcing a gun to have the gun at an angle of 45° to the surface. In such a position, the spray loss is approximately 65 per cent. If the gun trigger is not released at the end of a stroke

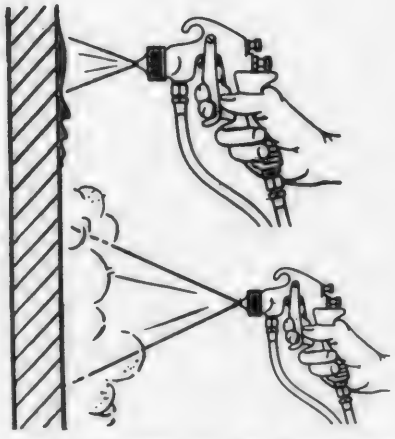

Fig. 1.—Upper: the gun is too close, paint goes on heavy and tends to sag; Lower: the gun is too far, causes excessive dusting and sandy finish.

The Author: John McCaslin holds a degree in electrical engineering from the University of Toledo, and is a registered engineer in Ohio. He has been with the DeVilbiss Co., since 1934.

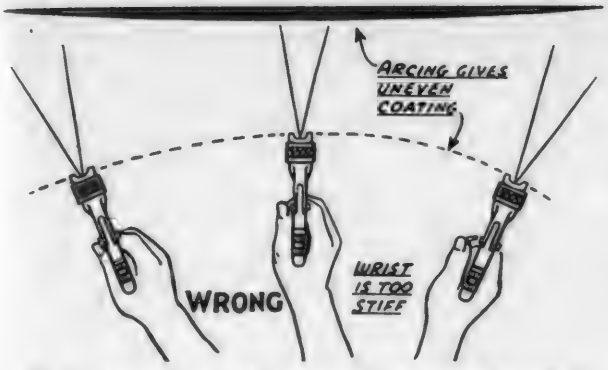

Fig. 2.—Arcing is caused by improper wrist action, and results in an uneven coating.

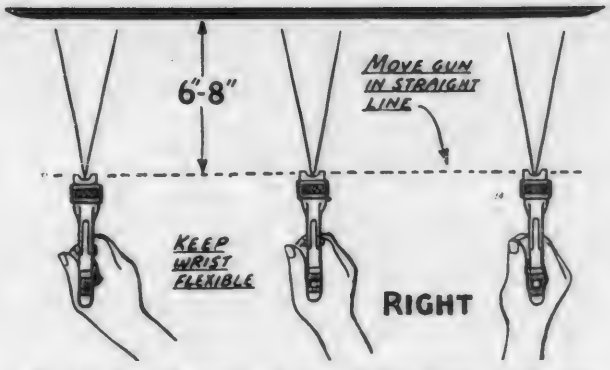

Fig. 3.—To avoid arcing and keep an even coating, keep wrist flexible and move gun parallel to work piece.

the material continues to flow and, in changing direction, the momentary stopping of the gun results in a pile up. To avoid further piling, the operator turns his gun off the surface. In doing so, it is not uncommon for him to spray as much as six inches beyond the area to be coated.

To check for inefficient operation, look for operators who whip their gun at excessive speeds. Check for excessive gun distances and arcing of the gun, and notice whether the gun is spraying the surface to be coated or the atmosphere.

Equally important are losses caused by improper pressure adjustments. It is not possible to observe an operator and determine if he has either too little or too much fluid flow and too low or too high an air pressure. In a furniture plant however, one would question air pressure over 45 pounds on finish coats, 35 pounds on sealers, and 25 pounds on wash coats and stains. The air pressure should be the minimum required to permit proper flow out on the surface, and it should not be used as a correction for improper fluid velocities or solvent balance.

Fluid pressures are more elusive because of the variation in friction losses due to viscosity, hose diameters and lengths, as well as the various fluid tips used. It is easy, however, to make a quick check on whether the fluid adjustment screw is wide open. Material flows should be controlled by the material pressure and the fluid tip selection, and not metered by the needle travel.

The optimum fluid tip orifice and air cap should be selected by actual test. Large fluid tips should be avoided, since they result in low fluid pressures, which are uneconomical and difficult to control. Too small a fluid tip results in too high a stream velocity. High stream velocity can also be the result of metering the material with the fluid needle. If the fluid stream velocity is too high, the atomization air will be increased in an effort to prevent a heavy centered spray pattern. High atomization air is responsible for a large percentage of the spray losses in a finishing room.

Controls

Lack of control is responsible for much of the poor spray technique in the finishing room. An example is a plant in which automatic machines were installed to spray a portion of the job, the remainer of which was sprayed by hand. Considerable difficulty was experienced with the machines each morning, whereas no difficulty was encountered with the hand spray. During the night, room temperature dropped considerably with a resultant drop in the temperature of the material in the circulating systems. As a result, there was a constant change in material temperature and viscosity during a period of 1 to 1½ hours each morning. The hand sprayers automatically changed their technique to conform to the new set of conditions. Other factors are worn spray equipment or inevitably a change in seasons. Before a spray operator can attain a constant spray technique, there must be good control over the other factors in the finishing room.

Material must reach the operator at a constant temperature hour to hour, day to day, and season to season. Any variation in temperature of the material affects its viscosity and, consequently, the flow rate from the gun and the degree of atomization.

It is not uncommon to find broken gages, inoperative regulators, worn fluid tips, and battered air caps on a spray line. Proper maintenance and care of equipment would not normally be considered a control, but any variable that affects the end result must be controlled. It is imperative, therefore, that the equipment be the same from day to day if the same finish is to be obtained.

With complete control over the material and equipment, it is then possible to control the spray technique. All operators should spray the same areas in a like manner. They should spray according to prescribed methods. Spray operators should become automatic in their spray technique. The basic fundamentals of good spray technique are comparatively simple in their application, and will result in maximum production in the form of more efficient spraying, greater economy, and the highest quality finish.

Training the Operator

Necessary control of material and equipment can be recorded with instruments and by a check list. The training of the operators is a more difficult task. Many equipment manufacturers and material suppliers have facilities for such training. This, however, is an initial training and will only start a finishing room on its way to more efficient spraying. If interest is not maintained in the program, old standards again become prevalent in 6 months to a year. A conservative estimate of the savings in a finishing room would be 10 per cent of the paint bill.

Most spray operators take pride in the finish that they produce, and will appreciate a program that will permit them to obtain a higher quality job.

The fundamentals of good spray technique consist of: a 50 per cent overlap of the spray pattern; a gun speed of approximately 250 feet per minute; a gun distance of six to eight inches; holding the gun perpendicular to the surface; and triggering the gun at the beginning and end of each stroke.

The best finish would be obtained if material could be poured on the surface and allowed to level out to a uniform film. This, of course, is not practical in production. The next-best finish is obtained by applying a full wet coat that will not sag or run. Since it

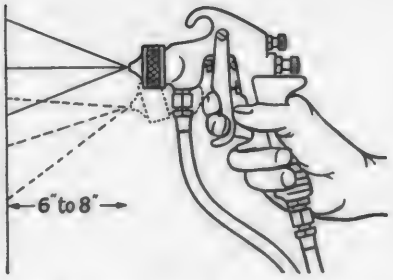

Fig. 4.—Gun should be held perpendicular to the surface. Tilting the gun up or down gives an uneven spray pattern.

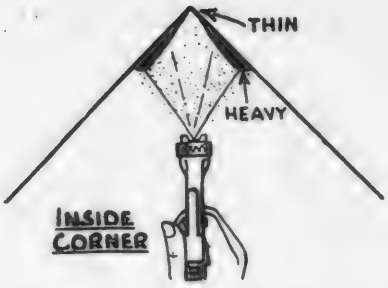

Fig. 5.—Spraying directly into the corner gives an uneven coating, but is satisfactory for most work.

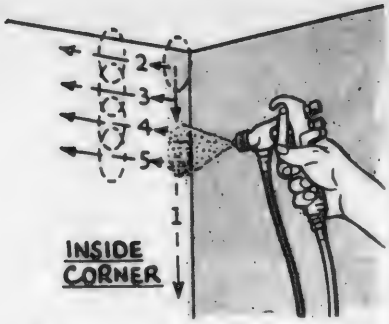

Fig. 6.—Spraying each side of the corner separately gives an even coating. Use a vertical spray pattern.

is necessary to spray all the material possible on a vertical surface without sags, any variation in the amount of material applied will result in either a sag or dry spray.

The average operator sprays with a multiplicity of passes at a high atomization pressure to produce a dry finish that will not sag, no matter how careless he may be in his spray technique. If the operators can be taught to spray a full wet coat regardless of surface absorption or solvent balance, it is then possible to control the amount of material that he can spray by adjusting the solids and solvent balance of the material.

The gun speed must be constant, since the flow of material from the gun is constant. Generally, a gun speed of 250 feet per minute is adequate. Higher gun speeds tend to distort the spray pattern and do not allow the maximum amount of material to reach the surface.

A 50 per cent overlap is obtained by aiming the gun at the bottom of the previous pattern. More than a 50 per cent overlap results in wasted strokes, while less than 50 per cent results in streaks. The fluid flow from the gun should be sufficient to apply half of the required film build per gun stroke.

A spray gun developing a spray pattern eight inches wide at eight inches from the surface would distribute all of its material over an eight inch wide area, each stroke. If the gun were held six inches from the surface, it would distribute approximately the same amount of material over a six-inch-wide band. If adjustments are made to spray at eight inches, then all of one cabinet, and each of the cabinets, must be sprayed at eight inches. Otherwise, there would be a variation in film thickness and if a full wet coat is sprayed with a minimum safety factor, the operator would have sags at those times when he had the gun closest to the surface. The reason for the range of six to eight inches is to take care of the variation in the skill of the operators. If they are unable to spray at the eight inch range, they have insufficient skill for the job.

The gun should be held perpendicular to the surface except for special conditions. Arcing the gun does not permit the spraying of a full wet coat because it is impossible to maintain a constant gun distance.

Angling the gun to the surface in the other plane usually happens when spraying areas such as the tops of pieces farthest from the operator, or the bottom of the pieces near the floor. This wastes material and, since one end of the spray pattern is closer to the gun than the other, causes an uneven material distribution with resulting streaks in the surface. In spraying the bottom of the cabinets, the gun should be turned over. In spraying the back edge of the tops, the difficulties can be minimized by rolling the gun over approximately 45 degrees.

Triggering the gun is the last spray technique discussed with the operator The purpose of triggering is to permit the operator to spray on the work, or overlap in the middle of a panel. When not triggered, the gun is usually turned around off the work. This wastes material and results in "shooting" a dry spray over an area that either has been or is going to be coated.

In furniture finishing, the corners are a constant source of trouble in the rub room because, in the average operation, they are never deliberately sprayed. With the normal arcing of most operators, the gun is never pointed directly at the corner. When the operator triggers the gun, he can edge all cabinets by spraying directly at the corner and, at the same time, coat both adjacent surfaces for approximately two inches. He can then fill in the rest of the panel without double-coating the two-inch band. To do this, it is necessary that the trigger be released just before it reaches the edge of the panel. Not only is the finish of higher quality but it is more economical because the gun is only on while it is over the area being sprayed

In spraying as in other operations in the plant, there must be one sequence of operations that is better than an other. Before a part is turned over to production, the minimum number of passes and gun reversals, the number of times a gun breaks over the edge and so forth, should be considered.

It is rather difficult for the operator to practice all new phases at one time. It is best that one principle be tried at a time until it has become a habit.

In adjusting the spray technique of an operator, it is necessary to also adjust the atomization air and the fluid flow. It should be remembered that, if runs occur, an investigation should be made to determine if the pressures are right. Often the operator reasons that moving the gun in close causes slags. Actually, sags are usually the result of too high a fluid flow. The same is true of reduced air pressure. Invariably, when the atomization air is lowered, more material is deposited on the surface. Again, the operator is apt to increase his air pressure in an effort to correct for too high a material flow. If the operator is taught to move in and spray at the right distance, or if the atomization is lowered, other adjustments should be made. In most cases, the finish obtained under present methods are too dry, and the newer method results in a better finish.

When the initial training on the line is in effect, any major correction of a spray operator's technique should be done in a spray booth away from production. It is not good practice to correct an operator in front of his fellow workers. Another advantage is that the operator can concentrate on what he is doing and try to accomplish it without worrying about keeping up with production. This training booth can also be used by supervisors in determining the proper spray gun motion study.

APPLYING FINISHING MATERIALS WITH THE Steinemann Pressure-Curtain Coater[1]

E. S. JOHNSON
Professor, School of Engineering, North Carolina State College, Raleigh

Flat panels and profiled parts are finished virtually without waste. Coater can handle polyesters and difficult-to-apply synthetics. A pre-heater may considerably shorten drying times.

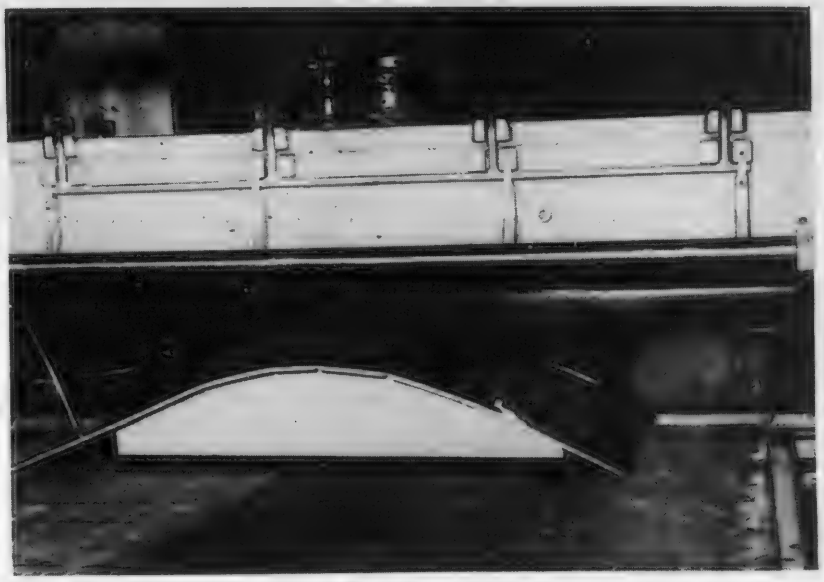

Fig. 1.—The continuous film of finishing material is visible here as a curved panel passes through on a moving belt.

THE STEINEMANN COATER is the result of a search to find an economical method of applying finishing materials to flat or shaped wood parts. In this process, a pressure head pours a controlled-thickness curtain of finishing material on parts as they pass beneath the head on a rapidly moving conveyor as illustrated in Fig. 1. By regulating the conveyor speed, head-slot opening, head heighth above the work, and fluid pressure, liquid materials can be applied to practically all flat surfaces and to many edges and profiles. The excess material is caught in a trough beneath the head, returned to the material reservoir, and recirculated by a pump to the pressure head so there is no loss of material.

History

In Europe as in the United States, there has always been a high degree of interest in obtaining improved methods of coating flat panels, but there has been a greater interest in Europe for methods of coating furniture parts. Most European homes do not have bedroom closets, therefore a large wardrobe is the major item in a bedroom suite. Since these wardrobes are usually 2 feet deep by 7 feet tall and 4 to 10 feet wide, they must be fabricated with "knock down" construction in order to move them up narrow stairs to reach bedrooms. Formerly these individual parts were finished by hand with the "French Polish" method of rubbing. As labor costs rose, spray guns began to be used. Because of high material costs, roller coaters were introduced after the end of World War II, but spraying was necessary for the final coat to obtain the quality level desired on flat panels and for additional coats on profiled parts. Because of the waste from the spraying method and the limitations of roller coating, the search for an improved method led to the Steinemann pressure curtain coater.

The original curtain coater was developed in a Swiss furniture factory in 1955 by Mr. Zehnder, whose rights were purchased by Steinemann in 1955. The original machine was installed in a furniture factory in Switzerland on November 24, 1955, and has been working in normal production since February 10, 1956. The original machine consisted of a head with a slot in the bottom through which lacquer poured on parts as they passed beneath the head on a conveyor. Since the original prototype, a pressure head with an air cushion was developed, the design of the head pouring slot was modified to pour a film of controlled thickness along the width according to the product to be coated, a tilting conveyor was developed for coating profiled mouldings, a machine was designed for coating complete television cabinets, and a tilting head was added for coating rounded corners. These machines are now in common use in western Europe for coating such products as furniture parts, television cabinets, plywood, hardboard, insulation board, acoustical ceiling, flooring, asbestos cement board, and metal parts. The first installations of the Steinemann coaters were made in the United States in 1958.

Process Description

The Steinemann coater will apply a uniform wet film to flat surfaces of practically any material that will flow. There are limitations of minimum wet film thickness that can be applied, depending upon the solids content, viscosity, surface tension, and other properties of the liquid material used. The

[1] Presented at Session XII, Wood Finishing, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

The Author: Sigurd Johnson holds an MF from Duke University. Before joining the North Carolina faculty, he was associated with the E. S. Johnson Engineering Service. Mr. Johnson is also active in consulting work.

Fig. 2.—This double-headed machine has separate pumping systems for applying component parts of difficult-to-control, chemically reactive materials such as polyesters.

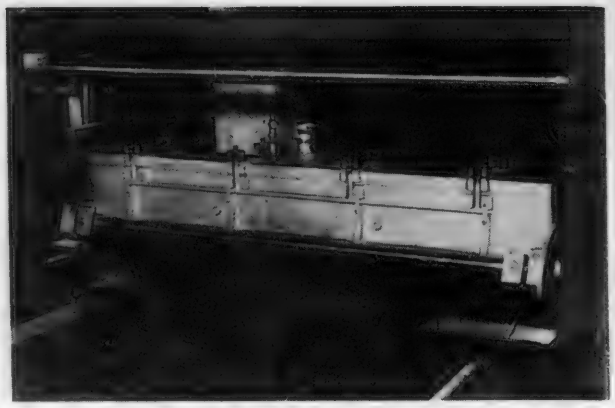

Fig. 3.—Steel lips at the bottom edge of the aluminum casting control the thickness of the film being applied.

limitations are more critical when coating vertical edges and profiles. The ability to "wrap around" corners and profiles and the avoiding of fatty edges and runs on vertical surfaces usually requires modification in finishing material formulation. Experience has shown that finishing material suppliers must work closely with the users of the equipment in order to develop formulations that will work in production.

Successful applications are operating with nitro-cellulose lacquers, sealers, toners, pigmented ground coats, urea-alkyd resin varnishes, polyesters, epoxy resins, vinyls, plastisels, paints, adhesives, and waxes. Other materials can be used, but experiments must be conducted to determine the proper formulation and operating conditions. Materials can be applied from ½ to 100 mils thick depending upon their characteristics and the parts coated. When the materials are formulated and applied under the optimum conditions the film produced is very smooth and requires a minimum of rubbing to produce a polished surface. When difficult-to-control, chemically reactive materials such as polyesters are applied, two heads with separate pumping systems are used to mix two component parts of the mixture on the work. Fig. 2 shows a double-headed machine.

Both labor and material savings are gained when finishing materials can be applied by the Steinemann coater. Experience at Wiederhold Lackfabrik, Hilden, Germany, has shown that material savings will range from 20 to 70 per cent, depending upon the size and shape of the part, compared with normal spraying. The equivalent of overspray on the edges is eliminated because all excess material is caught in a gutter, returned to the supply tank, and is recirculated to the pressure head. Since the fluid pressure is low, below 5 pounds per square inch, and no air is introduced in the applied fluid, there is no "fog" or "blow back" and all the material reaching the surface remains there in a smooth film. Since the normal machine operates in a range of 50 to 400 feet per minute, the production rate is far greater than spraying. Material handling can be reduced by placing the coater in a system of conveyors and drying areas so that the individual coated parts do not have to be placed in racks and handled manually between coats.

Machine Construction

The Steinemann coater consists of a steel framework supporting the head, gutter, pumping system, and conveyors for carrying the parts through the liquid film curtain pouring from the head slot to the gutter. The frame is made of steel, and is structurally designed to eliminate vibration. Vibration would cause ripple in the curtain and waves in the film on the work. The nylon belt conveyors pass over the infeed table, under the gutter, and over the out-feed table, and are infinitely adjutsable in speed in a 1 to 3 ratio such as 100 to 300 feet per minute. A typical operating speed with a 25 per cent solid nitro-cellulose lacquer might be 200 feet per munite.

The gutter drains into a pipe, which leads to the material storage reservoir. A pipe from the material storage reservoir feeds a gear pump, which forces the finishing material through a filter and feeds the pressure head through a plastic pipe. The head pressure is adjustable through a by-pass valve arrangement that regulates the material flow to the head. The head is a ribbed, reinforced aluminum casting with adjustable-opening steel lips running along the entire bottom edge, as shown in Fig. 3. The steel lips can be adjusted for a uniform slot opening varying from 0.008 inch to 0.196 inch.

The Steinemann Coaters are made in various sizes and types. The normal types come with conveyors and head widths for coating stock up to the following maximum widths: 12 inches, 24 inches, 43 inches, 51 inches, 63 inches, 75 inches. Wider machines have been furnished for the hardboard industry, and are made on special order. Most models come with one head and pumping system mounted with a space left for the addition of a second head, gutter, and pumping system at a later date is required. Fig. 4 shows a 12-inch wide machine that is made with a long tilting conveyor belt to facilitate the coating of profiles. Special lips are made to apply a uniform film thickness to corrugated surfaces. Various length infeed and outfeed conveyor belts are used, depending upon the length of the stock to be coated. Fig. 5 shows a special machine that has been developed for coating complete radio and television cabinets.

Operation

In the normal operating procedure, parts are placed on the infeed conveyor belts by hand or are automatically transferred there from another conveyor. The coating machine conveyor carries the parts through the pouring

Fig. 4.—This variation of the machine has a tilted conveyor belt for the coating of profiles.

curtain and deposits them on a conveyor carries the parts through the pouring curtain and deposits them on a conveyor for drying or to the hands of an off bearer who stacks the parts in racks for drying. The height of the head above the conveyor is adjustable from 0 to 10½ inches, but is usually set at approximately 4 inches for flat work. Curved parts are limited in height according to the sharpness of the curve, with a maximum of 6 inches for easily coated parts. Vertical edges are limited to approximately 1½ inches. Rectangular parts must be run with the edges at an angle of 45 degrees to the conveyor belt travel in order to coat the two leading edges. If all four edges must be coated, two passes must be made through the liquid film curtain.

Material viscosity must normally be in the range of 20 seconds to 80 seconds in a number 4 Ford Cup. Higher viscosities present entrapped air and pumping problems, but materials up to 200 seconds or more viscosity can be handled with a centrifugal-type pump. Heatable storage tanks are available, and the head can be heated if necessary. Vinyls can be applied as thin as 0.0008 inch wet film thickness, but nitro-cellulose lacquers are limited to approximately 0.0016 inch wet film thickness minimum. The nitro-cellulose type can be applied up to 0.020 inch wet film thickness, and polyester type coatings and plastisols can be applied much thicker.

Experiments must be made to determine the exact film thickness desired and possible to obtain. The usual operating procedure is to adjust the slot opening and fluid pressure to obtain the optimum smoothness of coating, and then to vary the conveyor speed to obtain the exact film thickness desired. Flat surfaces are relatively simple to coat, but profiles and edges require adjustments in fluid pressure and material formulation in order to obtain the optimum coverage. Experiments must be made for each application.

The most recent developments of the Steinemann Coater concern the use of pre-heating wood parts for greatly reduced drying times. These units heat the wood surface to approximately 250° F. to a depth of approximately 0.010 inches. This heating cycle requires electric radiant heat of high intensity for closely controlled cycles varying from 10 to 180 seconds. The heated parts are automatically released and passed through the coater upon reaching proper temperature. The cold finishing material striking the hot wood flows to the bottom of all surface openings and begins to cure from the bottom as the heat drives the solvents to the cool liquid surface. Drying times of two to three minutes for nitro-cellulose type materials have been obtained by this process. A unit for 4-foot by 8-foot panels requires a 36 KW heating unit, and would typically produce 30,000 square feet per day, depending upon the pre-heating cycle required for the finishing material used and drying cycle required. A limited amount of after-heating will reduce the total drying cycle time.

Fig. 5.—A special machine was developed for applying a continuous coat to complete radio and television cabinets.

Two units are now beginning production in Germany, but it is too early to give results of their production experience. A similar installation using hot air convection pre-heating is planned to begin production in July in the United States in conjunction with one Steinemann coater applying a sanding sealer and a second coater applying a synthetic urea alkyd resin varnish. It will be extremely interesting to watch the development of these fast curing systems in Europe and the United States.

Conclusion

The Steinemann pressure curtain coater is one more step in the technological development of processes and equipment that has characterized finishing for the past ten years. If this process is as successful in the United States as it has been in Europe, it should provide a useful tool for those manufacturers interested in reducing costs and improving the quality of their products.

Discussion

Kenneth Norwine (The Pilliod Cabinet Co.): How efficient is the filter that is being used?

Mr. Johnson: Quite efficient, but there cannot be a lot of dirt in the room.

A. J. Kirsch (American Cyanamid): Please summarize the advantage of the flow-coating application as compared with, say, roller coating.

Mr. Johnson: Pressure-curtain application has distinct advantages over roller coating. The main advantage is that the coating material is applied absoluetly uniformly on the stock, regardless of variations in thickness or profile of items to be coated. An example of this is an end panel for a furniture case that is made of hardboard with a frame around the outside. On occasion, this panel will deflect in the center under pressure of the roll, but since there is no contact with the Steinemann application, no deflection occurs and a uniform film thickness results.

Another advantage is that there is no set-up time required in changing from one thickness of stock to another, since film thickness is a function of the transport speed and quantity of material being circulated through the system. Stock thickness changes have no effect on film thickness.

Also, it is possible to apply material of almost any viscosity through the pressure-curtain coater, whereas with the roll-coating application it is very difficult to apply many types of materials uniformly.

L. H. Martin (Minnesota Mining and Mfg. Co.): How many installations of this machine are there in this country?

Mr. Johnson: About eight.

L. A. Patronsky (Timber Engineering Co.): How much longer does it take to clean this apparatus than conventional application equipment?

Mr. Johnson: No longer; it takes about the same time as conventional spraying equipment but less than a roller coater.

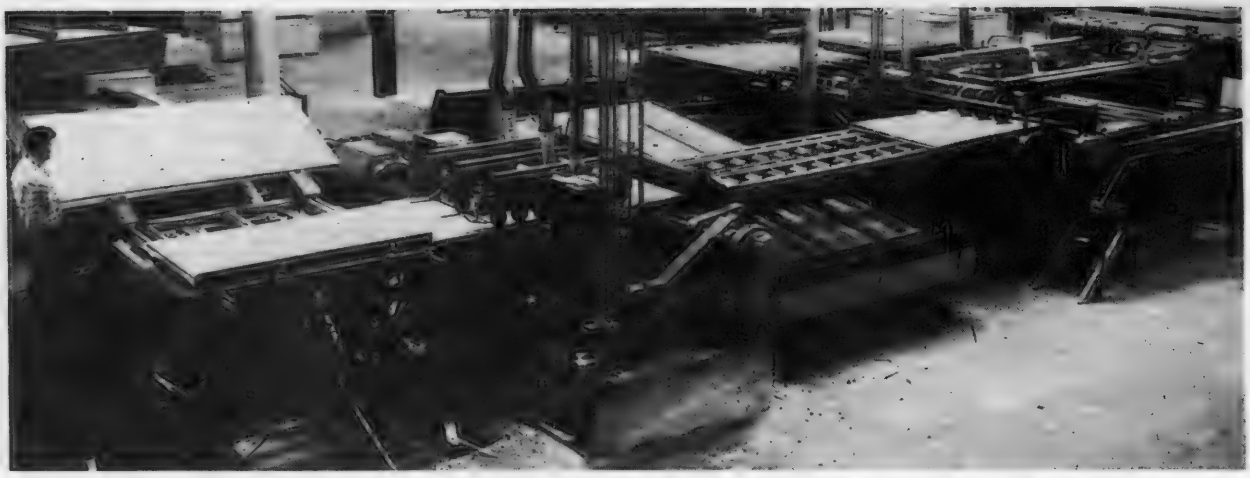

Fig. 1.—This one man controls the entire operation, including infeed, both sawing machines, the transfer between the first and second machine, and the outfeed stacker. Previously, the operation required three men to produce but slightly more than half the present production.

RECENT DEVELOPMENTS IN Double-End Tenoners and Borers[1]

K. V. White
Sales Manager, Greenlee Bros. & Co., Rockford, Illinois

Tenoning is not the most important operation for the double-end tenoner, so emphasis is on modifications and attachments to speed up secondary operations. These include automatic feeding, stacking, and handling between machines, and so forth. Methods of increasing the feed rate are discussed. Variable boring speeds and methods of feeding are mentioned.

THIS PAPER WILL DEAL with double-end machines in general instead of the double-end tenoner only, since double-end tenoning is by no means the most important operation for this type of machine. In fact, many users do no tenoning at all.

What, then, is a double-end tenoner? As far as Greenlee Bros. & Co. is concerned, and we know enough about our competitors to realize their viewpoint is about the same, there are many users of the conventional or standard type tenoner, and there probably will continue to be many.

Of more importance today, however, is the versatility of design that enables us to use the basic double-end machines to build specialized single-purpose or multiple-purpose equipment by combining standard and special attachments. Therefore, let us look at some of the recent developments.

The one advancement that is asked for by everyone is more production per man hour of labor. This is a problem that can be approached from several directions: More pieces per minute through the machine with the same labor, a reduction of labor hours for the same quantity, less down time for set-up changes, a reduction of scrap, and reduced maintenance and repair time all lead toward the desired result. Now let's examine the recent approaches to the solution of these related problems.

Increased production is more complicated than simply speeding up the machine, but of course, this also is often necessary. Not too many years age we were limiting chain feed machines to 30 feet per minute where now speeds of 200 to 300 feet per minute are not uncommon. This increased speed brings up problems of more rapid wear of the chains, tracks, and sprockets, so these parts are now designed to stand up under the more severe conditions.

Horsepower requirements normally increase for the faster feed rates, but of course building larger units is a simple matter. The cutting equipment must be studied carefully, because the speed increases may dictate more knives or teeth, jointing the tools on the machine, better grinding facilities, changes to carbide tooling, or other such factors. The spindle speed may have to be increased by using belted units or high-frequency operation, and this means better bearings, precision dynamic balancing of the rotating assemblies, and perhaps different, more positive lubrication methods.

Of course, the faster feed rates do no good unless the stock can be handled into and out of the machine. In many cases, this means infeed and outfeed assists such as conveyors, automatic elevators, stackers, or hopper feeds. These are relatively simple for operations where the parts are uniform, and they can vary all the way to the impractical where there is a wide variety of parts. For example, hopper feeds work out better for small pieces, but the production of small parts is often greater by hand feeding because the operator can place a great many ahead of each dog or lug.

The second approach is to reduce the labor for the same quantity of pieces. This is closely associated with the previous discussion in that the faster feed rates will enable the operator to get the job done quicker. But here we are bringing in automation, or devices to eliminate costly handling. In many plants it is difficult to do much along this line because of the variety of work, but other industries, like the panel plants for instance, can and have done much. Almost all the recent installations include automatic

[1] Presented at Session II, Wood Machining, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

The Author: Kenneth White graduated with a BS degree in mechanical engineering from the University of Iowa. He joined Greenlee in 1949, was promoted to Assistant Sales Manager in 1956, and moved up to his present position in 1957.

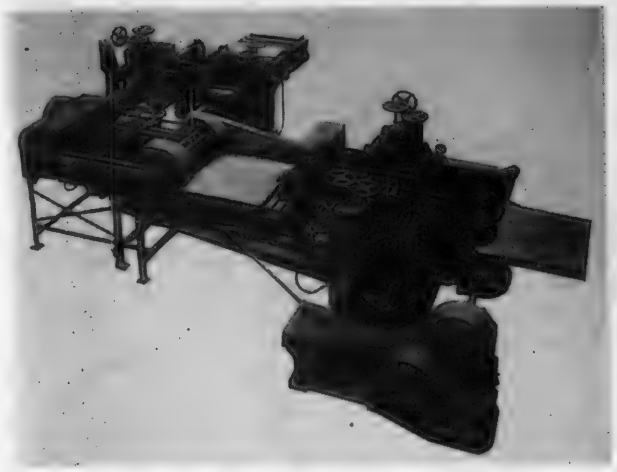

Fig. 2—These two special machines(with an automatic transfer unit between) split nine 12- by 12-inch squares from this large sheet of acoustical material.

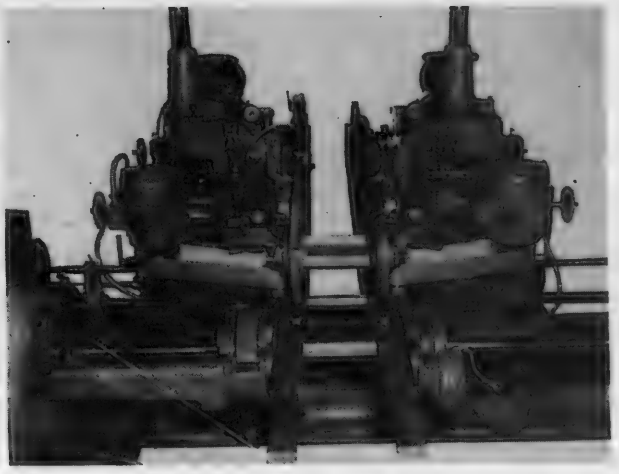

Fig. 3.—Oscillating belt-type sanders are mounted in standard dado position to sand both sides of built-up table tops in one pass.

transfers joining the skinner or ripping saw and the cut-off saw to eliminate the man feeding the second machine. These, coupled with automatic stackers and infeed assists, result in great labor savings. Greenlee has supplied this type of specially designed equipment to plywood, particle board, mineral tile, fiberboard, and flush-door plants.

As an example of the savings involved, there is a recent plywood installation where one man controls the infeed, two sawing machines, the connecting transfer and the stacker, and handles panels at over 300,000 square feet in one 8-hour shift. Compare this to the former arrangement of 3 or more men working 8 hours for slightly more than half of the production.

Other industries, too, are thinking along these lines. It is not uncommon to find conveyors between the double-end tenoner and a moulder in a sash plant or some similar installation in a furniture plant.

A third approach is to reduce the down time of the machine for set-up changes, and perhaps this is of prime importance to most double-end machine users since the majority are faced with frequent set ups. A great deal of study on this problem has resulted in indicators that tell the distance between the feed chains to within a half of 1/64, actually closer than the operator could measure with a rule. All cutting units have scales to show the horizontal, vertical, or tilting adjustment. Some of these, like the tenon units, have connected adjustment so either one or both motors can be moved, depending on whether the operator wants to change the distance between the heads or merely change the cut with relation to the chains.

Other machines have power adjustment for the units to speed the set-up changes. Split-type saws or dado units that can be dropped into the cut individually eliminate the need for pulling the shaft to make changes. Also used at this point are cartridge-type units that have a quick-change feature so one shaft can be set up while the other is in use. Along this same line, many users like the sleeve mounting of cutters because they can buy a duplicate set of sleeves, or perhaps a sleeve for each head set-up, so it is a simple matter to place the heads. This is especially valuable where more than one head is used on an arbor.

Templates or gages have been used to advantage in making set-ups because this is an easy means of placing the cutters properly with relation to the feed chains.

Naturally, a well-trained operator is one means of assuring the best performance of a machine, especially one as complex as the double-end type. While all manufacturers supply factory demonstration men with a new machine, it is suggested that periodic visits will be valuable and may be almost essential if a new operator is on the job. It is always recommended that more than one man be broken in on a machine like the tenoner. Many times, too, a visit to the machinery manufacturer's plant is helpful to get the operator to appreciate fully the equipment he is responsible for.

Scrap reduction, the fourth point, can be helped in many ways, including the proper training of the man. Some recent machines have had large speed indicators so the supervisor can tell at a glance that the job being run is at the proper rate, not too slow for cost purposes and not so fast as to cause scrap from improper cuts.

Certainly included here also is the proper selection and maintenance of tools. There are many other obvious points that are all tied in with operator experience and training, but it might be well to mention that most double-end machines have safety stops to prevent jam ups, and can be supplied with devices such as rubber chain pads to prevent marking of delicate stock.

The fifth and last point, the reduction of down time for maintenance and repair, is partly built into the double-end machine initally and partly a result of adequate time allowed and proper instruction for the plant personnel. Experience in building machines enables us all to design toward eliminating any weak points, and of course, any errors in this regard are soon corrected. Other steps have been taken, such as the use of sealed motor bearings, new materials for the chain tracks and other points that are subject to sliding wear, automatic force-feed oilers, hardened parts where required, and totally enclosed motors. Preventive maintenance is a good practice, and a few minutes spent periodically by a qualified mechanic or serviceman can prevent some costly breakdowns.

What of the other points that we concentrate on? Safety is certainly one major area, and the trend in double-end machines is toward the machine tool construction. Dust-tight control cabinets, totally enclosed motors, master stops at convenient points, automatic stops for thick stock, 110-volt control circuit, indicating light to guide the operator, and proper hooding and guarding of moving parts are some of the points that get proper attention today.

The versatility of double-end machines was discussed at the beginning, and a few of the applications that have recently been made to the basic tenoner should be mentioned. Of course, we all like to do the maximum number of operations in each handling, but each problem must be studied to be

Fig. 4.—This tilted, 2-spindle drilling attachment drills ceiling joists.

sure that the extra operation on a tenoner does not slow down the entire job to the point where we would be better off to handle the part twice. We have been successful in drilling pieces just as they come off the tenoner, and other applications are possible where the drilling unit travels with the work. Belt-driven dovetailing spindles can be applied to make the dovetail groove behind a straight dado saw.

Sanding is another operation that is of considerable interest, and disc, wheel, drum, formed belt and oscillating belt units have been coupled to the tenoners to edge sand after the regular double-end machine operations.

Of course, there are the jump-dado, cam-operated irregular shaping, and window-frame or swiveling tenon units that are not exactly new. In recent months, however, modifications of these have been made to increase their usefullness.

There seems to be no limit to the special units that can be added to make this already versatile double end even more useful. Each plant has its own problems, and all manufacturers are glad to work on these problems.

The double-end type machine is not restricted to wood parts or the various panels, of course. Aluminum can be handled very nicely and cuts a lot like wood. Many other types of material have been run on these machines, such as the various laminates, plastics, transite, glass fiber products, and others.

For as many years as the double-end tenoner has been built, it would seem as though there should be and end to the different applications. This is not the case, however, and it is no wonder this versatile machine is often called a woodworking plant in itself.

Developments in Borers

Being one of the basic operations in most plants, boring is an area that will get a lot of entensive study from now on. The machine users are not going to be willing to use the standard type of equipment if there is a better way of handling their work.

One of the most important fields to investigate is the relationship between bit speed and feed. Especially on the gang boring machines, very little has been done to give a selection of spindle speeds, and these are now pretty much a compromise—too fast for some of the larger bits and too slow for the smaller sizes. It is hoped that it will be economically feasible to offer equipment with variable spindles so the user can get the maximum benefit from his tools and equipment.

At the moment, the answer to a lot of boring problems seems to be some means of keeping the machine full, or of hitting every stroke. Hopper feeds have been built, of course, and the aim is to design enough flexibility into the hopper so it will handle a wide range of stock sizes. Some type of return conveyor or chute is often valuable so that the operator can load and unload from the front of the machine.

As far as Greenlee is concerned, these automatic feeding devices are important enough that our two newest machines were designed with a stationary table. It is believed that the fixed table and bit feed will work out much more conveniently for these feeding devices, and will also give greater convenience to the operator for hand feeding work because the loading station is always at the proper height.

Large panels or built-up assemblies can be worked to good advantage on equipment with an open back because conveyors can be added to get the work into and out of the machine.

The reduction of set-up time is most important in the boring machine line, too, and equipment available today has set-up controls for inching or jogging the feed to the pattern or template used for positioning the spindles.

This brief description of double-end machines and boring equipment will, we hope, lead to some questions. Manufacturers are all most sensitive to the requests and comments from users and potential customers, and the need for better equipment coupled with the competition between machinery manufacturers will lead to many outstanding developments.

Significance of Knife Marks

ON LUMBER CORE SURFACES

J. E. Hyler
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Laminated assemblies faced with veneers often contain lumber cores, which must be run through a surfacing planer before they may be glued up thickness-wise with other plies. Many woodworkers have been puzzled by the fact that, where a seemingly perfect job of planing has been obtained on such cores, with no knife marks showing, the glue room nevertheless does not obtain as good an adhesive bond as it often does with lumber-core stock with rather pronounced knife marks on the surfaces.

The reason is that material that has been dressed with knives jointed rather heavily, so that rather pronounced 'heels" have been developed on the knives immediately behind the cutting edges, is subjected to an ironing-out effect. That is, these knife-edge heels "iron down" what would otherwise be the ridges between knife marks, so no knife marks are visible. In doing this, however, the heels behind the knife edges really compress the ridges.

Such compression closes the pores in the wood and other tiny interstices in the surface. Therefore, glue cannot penetrate effectively. A better gluing job is actually obtained when no such ironing down of ridges between knife marks occurs. Men who have studied this therefore become exponents of one-knife planing, as it is often referred to. This means planing with knives that have not been jointed wherever lumber cores are being processed.

The ironing-out effect on ridges between knife marks is always a matter of degree. Thus, if one is using jointed cutters on which heels are exceedingly narrow, showing only as a light silver line after cutters have been jointed, the amount of compressive effect they exercise on knife-mark ridges will be lessened. The real point is that one should never be deceived into thinking he has surfaces highly suitable for gluing and laminating simply because they do not show any knife marks.

The fact is that knife marks may be quite pronounced on lumber cores, yet a very good job of gluing may be obtained, with practically invisible joints. Invisible glue joints, however, depend to a considerable extent on use of light-colored adhesive, especially where woods being joined are light in color.

Fig. 1.—Operation view of modern surfacing planer, busy in the plant of General Woodworks, Council Bluffs, Iowa. *Photograph courtesy Greenlee Bros & Co., Rockford, Ill.*

FAST, MECHANIZED WAYS TO Unload Lumber from Box Cars[1]

T. P. McLaughlin and J. La Spisa
Moore Dry Kiln Co., Jacksonville, Florida

Proper box car design would simplify lumber loading and unloading. Twenty-foot-wide doorways will help railroads retain lumber traffic. Power feed rolls speed up removal of hand-loaded lumber.

Fig. 1.—With posts and interlace strapping removed, fork truck easily unloads a single package. A high-capacity lift could handle three pckages at one time. *Photo courtesy Seboard AirLine Railroad.*

As the inflationary spiral of wages continues, the lumber industry finds increased mechanization in all phases of operations necessary in order to maintain its competitive position. The reduction of cost in loading and unloading box cars is worth extensive investigation. Excellent possibilities exist for the reduction of man-hours required for these operations.

The advantages of mechanical handling are available to most manufacturers of competitive materials. At present, the shortage of box cars designed specifically for lumber shipments has forced both the shipper and receiver to absorb the higher handling cost or divert their traffic to motor freight.

Through the efficient application of various existing mechanical methods, costs can be reduced considerably. No particular solution is applicable in all cases, since the optimum solution is partially dependent on the installation's existing facilities. It is the intention of the authors to survey a few of the solutions available, hoping that they may solve the problems of others.

The problem of box car loading and unloading would be reduced considerably if properly designed cars were available. In the past few years, pressure has been exerted on the Association of American Railroads by industry, trade publications [2] and trade

[1] Presented at the Fall Meeting of the FPRS Northeast Section, held Oct. 31-Nov. 1, 1957, in New York City.

Fig. 2.—Prototype box car with doors in full open position exposes banded and buttressed packages. *Photo courtesy Seaboard AirLine Railroad.*

Fig. 3.—Properly interlaced packages are easily positioned in car with roll and lift combination. *Photo courtesy Seaboard AirLine Railroad.*

associations. Many railroads realize that new equipment is necessary if further diversion of their traffic to trucking is to be prevented. The construction of new cars with a larger door opending is expected to regain a portion of the lost traffic.

One railroad produced a prototype from a standard box car as shown in Fig. 1. The car has an inside length of 40 feet 6 inches, and a height of 8 feet 8 inches. Packaged lumber is made easily accessible for forklift unloading through 20-foot doorways, which are located at diagonally opposite ends. Each doorway is covered by *two* 10 foot by 7 foot 10 inch doors. These doors move in the same direction while opening, and in the full open position, one door overlaps the other. To prevent the load from moving against the doors, it is buttressed by two posts. The upper ends of these post are made of telescopic pipe sections that are hinged to the roof adjacent to the door. The lower ends are locked in pockets on the floor. These posts swing upward and are fastened to the car roof above the door opening to make the lumber accessible for unloading, as shown in Fig. 2.

This car has successfully proven itself many times. In one instance, a shipper loaded the car at Baltimore with twelve 20-foot packages of 2 by 12's. The lumber was packaged in units of 2 feet by 4 feet. The loading time for this volume was 11 minutes. The car was then transferred to Newark, where it was unloaded in 25 minutes. This operation was expedited by the use of two forklift trucks, unloading simultaneously from both sides of the car. The car was then reloaded in 20 minutes before going to another yard.

Naturally, the maximum efficiency of the new car is attained when both the consignor and consignee utilize the forklift truck for loading and unloading. However, the use of this car is flexible in most cases, as it will speed up unloading regardless of the method being used. The wide doors provide a maximum access to the load. The lumber can be passed directly out of the doors with a minimum of wasted motion inside the car. Since these packages are banded together, the lumber does not shift in transit. The load arrives in excellent condition, and minor annoyances such as lumber jambing the door shut and scrambled piles at the door are usually avoided.

This car appears to be a good solution, but at the present a few drawbacks exist.

When using the car in conjunction with certain existing handling methods, such as a stationary conveyor, it must be remembered that the car is designed for unloading from both sides. If this is impossible to arrange, excessive movement of half the load will be necessary. The car must also be spotted so both openings are accessible to the forklift truck.

The Seaboard Airline Railroad expects to have ten bigger and better new lumber cars in service by the end of the year. The new car will be 22 inches higher than the prototype, giving an inside height of 10 feet 6 inches. Additional vertical door clearance is being provided by increasing the door height to 9 feet 6 inches. This increased height will raise the 25,000 bd. ft. capacity of the present car to approximately 32,000 bd. ft. for the new, the exact footage depending on the package size. In some cases, this increased capacity will mean a weight increase of 15,000 pounds.

Earlier this year, the Car Construction Committee adopted a design for a general-purpose box car. This design has been submitted to all railroads for consideration. The proposal advised the adoption of a car 50 feet long with 16 foot staggered door openings. These openings are to be covered by one sliding and one plug-type door. The Car Construction Committee considers this design adaptable to both mechanized loading and bulk loading. This design is more versatible than a car specifically designed for the lumber industry. Although maximum facility of loading will not be obtained, a larger number of cars will be available for lumber shipments.

One manufacturer of steel strapping working closely with a Chicago lumber supply company, has developed methods of stacking, banding, and loading packages. The various methods devised are applicable to box cars as well as flat cars. These methods are descrip-

Fig. 4.—Unloader housing, with power roll extended through doorway, rolls on four tracks running perpendicular to the car. *Photo courtesy Paine Lumber Co., Ltd.*

Fig. 5.—Weather-proof installation is then produced when the unloader is rolled up to the car. *Photo courtesy Paine Lumber Co., Ltd.*

[2] See articles in the Nov., 1956, and March, 1957, issues of the Southern Lumber Journal.

tively presented in numerous pamphlets, which describe, step-by-step, the entire process from a single board loaded car. Methods of moving packages inside the box car, such as rolls, lift, chains and jacks, are clearly illustrated (Fig. 3). Strapping methods used on individual packages and unit car loads are diagramed. The methods devised by this manufacturer have proven successful and are being used by many manufacturers. In tests conducted, proper strapping of packages had reduced the shifting of packages to a negligible amount.

A large Wisconsin door manufacturer arrived at a rather unique solution to its unloading problems. A successful combination of a power roll, conveyor system, and automatic chain arm stacker was made in a unique housing. In developing this arrangement, the company was faced with the problem of unloading lumber from a box car fast enough to synchronize with an automatic stacker.

The unloader housing as shown in Fig. 4 is mounted on tracks running perpendicular to the car siding. After the car is accurately spotted on the siding, the unloader is rolled up to the car door (Fig. 5). This housing or moveable building contains a trough and conveyor system, which is adjustable to the desired height of the load in the car.

Inside the car, lumber is placed on a live roll, which projects through the car door. This roll as shown in Fig. 6 pivots to allow unloading from either end of the car and more or less "sucks" the lumber into the trough, where it slides to the bottom to center itself on the conveyor. At the present time, two men in the car are unloading approximately 56,000 bd. ft. per day. This mechanism does not require a specific door width, as it has been used in conjunction with 6-foot and 8-foot doors. To obtain best results from this unloader, the company has requested their shippers to use a special method of stacking. Flexibility is provided by using the second and third conveyor to obtain the necessary elevation to feed the rear chains of the high-level stacker. The stacker crew, which consists of four men, box piles the lumber into packages, which are discharged by gravity onto storage rolls where the forklift removes the package to the kiln loading area.

The unloader has met the company's expectations. It does the work of seven men, and has paid for itself in less than two years! The company believes it has obtained many fringe benefits through this unloader installation. There has been a great reduction in demurrage charges, and bad weather no longer delays unloadings, or makes overtime necessary.

Fig. 6.—Power roll propels dry lumber through the car door regardless of weather conditions. *Photo courtesy Paine Lumber Co., Ltd.*

The manufacturer also feels that the attitude of labor toward management has improved. The employees believe that management has helped them with the problem of lifting heavy lumber. The plant uses primarily ponderosa pine and fir. A small volume of hardwood, however, is also used. They estimate that greater savings are derived from handling hardwoods, since more pieces are involved than in a similar volume of softwoods. They have also found that the fast flow of lumber from the cars through the stacker makes it possible for them to eliminate the large inventory they used to carry.

At the present time, the authors know of two manufacturers who are producing power-assist rolls. These rolls are mounted on adjustable frames, which fasten to the door opening of the box car. These power assists are available in single- and multiple-roll design. One West Coast equipment company produces a power assist that has one power roll, a tension idler, and two driver idlers, as shown in Fig. 7. The lumber is placed on the first driver idler and fed between the tension idler and the power roll. This device rotates to permit unloading from either end of the load. The unit is adjustable in height from 56 to 94 inches in the car door. The mechanism tilts from the horizontal plus or minus 20 degrees. All rolls are covered with nonmarking rubber.

In one test, a crew of two inexperienced men loaded 3,100 pieces of 2 by 4's (27,000 Bd. Ft.) in three hours. The machine was approximately 40 per cent loaded, and according to the manufacturer, an experienced crew should be able to attain a machine loading of 60 to 70 per cent.

A single-roll power assist is also manufactured on the West Coast (Fig. 8). This unit weighs 135 pounds and is easily adjustable to the load level by one man. The unit incorporates a variable speed feature. The exact pulling force can be ascertained from experience. The manufacturer considers this equipment capable of decreasing loading and unloading time 10 to 15 per cent. With a proper conveyorized system on the off-bearing side, this percentage would probably be increased.

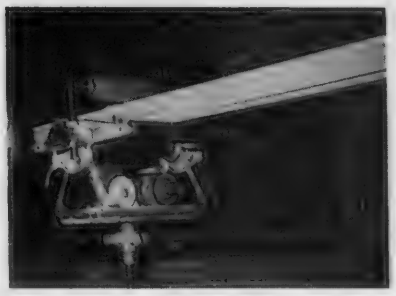

Fig. 7.—Multiple-roll power assist, in horizontal position, handles up to 6-inch bundle between tension idler and power roll directly below. *Photo courtesy Harshberger Equipment Co.*

The man-hours saved when using these rolls is dependent upon many factors. The speed of the roll controls the theoretical lineal footage capacity. The average board footage per piece affects the volume output. The number of men in the car, and the extent of their experience, controls the per cent of machine loading. The type of equipment, or operation, on the off-bearing side of the roll would determine the optimum feed rate.

Proper design is the most important factor in providing an efficient method of mechanized box car unloading. Regardless of the handling methods used, the design must produce a correct flow of materials. Modernization of existing methods is costly, but in most cases is profitable. New railroad sidings should be designed and laid out so the installation will be compatible with desired mechanical handling methods. Flexibility in a design is desirable. If possible, construction for both conveyorized and motorized handling would be preferable.

Fig. 8.—Single-roll power assist, made of light-weight materials, is easily adjustable to proper height by one man (note wing nuts over slotted section). *Photo courtesy Lenfesty and Shank.*

Packaging Lumber

SAVES TIME AND MONEY[1]

J. C. Fowler
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Packaging off the slick chain is predetermined by sales. Tallying in packages is described as related to strapping and mechanical loading. Cost analyses show advantages over hand loading.

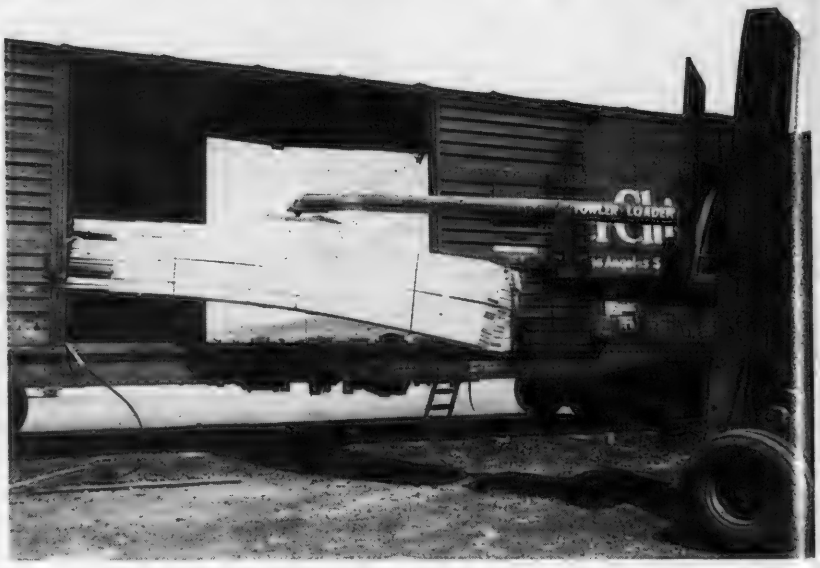

Fig. 1—The double-door car is necessary for loading the three-foot by three-foot package of lumber with the Fowler Loader.

HAINING LUMBER COMPANY is a medium-size lumber production operation. It has a production of approximately 100,000 feet per day or 22 million feet in ten months of operation. It has two sawmills, one circular mill at Peach Springs that cuts Indian Service timber, and one band mill at Williams that cuts Forest Service timber. The lumber is cut at the mills into six-quarter shop and selects and eight-quarter commons. It comes in this form to the planing mill at Williams, where the 6/4 is stacked and the 8/4 is resawn rough green into 4/4 and then stacked for drying.

The equipment consists of the usual equipment found at a planing mill. A resaw, breakdown to planer, ten-knife planer with a production of 150,000 lineal feet per eight hours, automatic smooth-end trimmer, slick sorting chain about 50 feet long, three fork-lift trucks, and two lumber carriers.

During the fastest drying season, we sometimes had to work two shifts to keep up with the dry lumber. As a result, when we started the morning shift, we would often have about 100,000 feet of lumber to load from the night shift plus whatever was produced that day. This created quite a loading problem.

Because we were very dissatisfied with the old hand-loading methods that have been used ever since the first car load of lumber was ever loaded, and since we had tried the package system, several years ago, of putting the packages on rollers, then rolling them into place (and found it too slow and expensive plus the fact that we could not get sufficient footage in the car), we decided to try a system that we had been thinking about for several years. As a result, the Fowler Loader was developed and a loading technique was worked out that enabled us to load a 30,000 foot car in slightly over one hour's time at a savings of 30 cents per thousand over the hand loading method. Now our entire production is packaged, and the packages are loaded for our own convenience.

This discussion will start with the lumber after it has been through the planer, surfaced, graded, and double-end trimmed and is on the slick chain ready to be pulled into packages. The discussion will be divided into several parts. First, and very important, is the necessity for cooperation between sales and shipping; second is packaging off the slick-chain in relation to shipments; third is tallying methods and strapping; fourth is description of methods of loading; and last, a cost analysis breakdown of man hours and material and a comparison showing the advantages over hand-loading.

Sales Cooperation is Essential

Cooperation between sales and shipping is the key to the success of this system. In our operation, grade yield from the log has been studied and we know about what percentage of each grade to expect from every width. Orders are taken in advance against this information. We are very fortunate in that our Sales Department is not only sales conscious, but is vitally interested in the operation as a whole. As a result, we are able to plan our production well in advance. Almost from the time the board is cut from the log we know on which order it will be placed. The shipping clerk and foreman are kept well informed of the orders, and are able to plan and ship them as the different grades develop.

In shipping packaged lumber, we know for example that when we ship the three-by three package we can load 18 long packages plus the six and eight foot shorts into the car. If we are shipping the two by two package, we will be able to load 32 packages plus the six and eight foot shorts into the

[1] Presented at Session XIV, Lumber Manufacturing, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

The Author: Jesse Fowler, in the sawmilling business 26 years, was associated with Jeffrey Lumber Co., Hall Lumber Co., Currier Lumber Co., and U. S. Plywood Co., in addition to owning his own business, before joining Haining. He developed the Fowler Loader.

Fig. 2.—Here the second tier of packages is being started before the third package of the first tier is put in place.

Fig. 3.—The completed load of 3-by-3 packages.

car. If the order should call for two-by-four packages, then we will be able to place 16 packages in the car.

We always ship the three-by-three package, unless the order specifies some other size, for two reasons. First, it is our most economical one to load. Second, we can get more footage into the car because three-foot-wide packages fill a nine-foot-wide car. Two-foot- and four-foot-wide packages leave one foot of idle space.

For any package system to work successfully, the shipper must be able to load as cheaply or for less money than he is able to hand load. He must also be able to save the customer money either in unloading, or if he does not have unloading facilities, by a car that arrives in better shape so he can unload by hand in less time and at the same time have less breakage and damage to his lumber.

For an example of how the system works, presume that for the day's run, there are order for two car loads and one truck load of 1-x-12 No. three common, and that we are shipping the three-by-three package. The chain crew is given instructions to pull the three-foot-wide package. They then know to pull them 40 layers high. When the first 18 packages are pulled, they are tallied for the first car. As the next 18 packages are pulled, the foreman keeps close tab on them, and, as the last packages are started, he gives the chain crew instructions for the next eight packages to be pulled four feet wide for truck shipment. As each order is filled, the chain crew is given instructions on the next order in advance. This same procedure is carried out with each grade that develops.

Keeping the Tally Straight

The question now comes up, how are the tallies kept straight with this method? As nearly as possible, the packages are pulled to the block system. That is, 16-foot lumber is pulled on top of 16-foot lumber, 14 on top of 14, 12 on top of 12, and so forth. It is not always possible to do this in a package, but in no case are less than four of the same lengths pulled together. This gives the tallyman a chance to count all the lengths, without losing a short length between two long ones. Each package is counted from the end after it has been moved from the chain by the carrier. The tally on each individual package is written on that package, and the pieces are then totaled. This total is then compared to the total number of pieces in that package. When the number of pieces and the tally match, it is then entered on a sheet for that particular order. Also, the box car number is put on the package along with an O.K. to load. This car number and O.K. are checked by the loading crew, and unless they find it so marked, the package is not loaded.

A strapping system was worked out with Signode that makes use of two ¾ by .028 inch straps per package and an automatic seal feed strapping machine. One man can strap 100,000 feet per day, and also keep carrier blocks picked up and help set slings for the loader.

Loading Methods

In loading we use one 16,000-pound lift truck with a Fowler Loader attachment. If we are loading four cars or less for that day, we use one helper to set slings and guide the packages into place in the car. If the loading schedule calls for five or more cars, we then use two helpers. These men prepare the cars for loading, set slings on the packages, and guide and place them in the car. They also tie the car down after loading and close the doors.

In the actual loading procedure, the swivel plate or head is set as near the center of the package as possible. Two ⅜-inch wire rope slings are then passed around the package and hooked up tight on adjustable lugs in the head. The lift driver then raises the package with the fork lift controls and approaches the car so the package enters the car lengthwise. It is then turned as it enters, and is placed parallel with the wall. One end of each sling is then unhooked, and they are withdrawn from around the package as the lift truck is backed away from the car. This complete cycle takes only about three and one half minutes. Each package contains approximately 1500 to 1800 BF of lumber.

We have worked out three basic types of loads. First is the conventional method where the packages are placed to each end of the car as in hand loading. We use this method altogether unless the order specifies another. With this method, the greatest amount of footage may be placed in the car. A 40-foot car will contain approximately 32m BF. Two 1¼-inch steel straps are placed in each end before loading, and they secure each end after loading.

The second method is the staggered method with the 3-foot by 3-foot package. In loading by this method, the first tier of packages is placed to the far wall and to the end of the car. The next tier is then placed against the first one but the end is left about three feet from the end of the car. The third tier is then placed about six feet from the end of the car. The opposite end is then loaded with this procedure reversed. Three 1¼-inch, high-tension straps are placed around the entire load. This gives a floating load that does not require any bulk heading and is very easy to unload. With this type load, a 40-foot car will contain about 27m BF of lumber.

The third type load is a staggered load again, and makes use of four-foot-wide packages. It differs from the second in that the load is placed six inches from the sides of the car, and

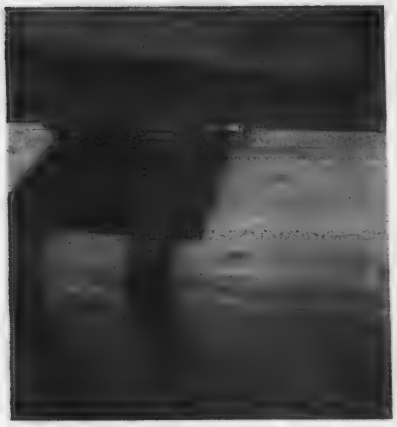

Fig. 4.—This new swivel plate makes use of 6-inch-wide nylon web belt slings, which will not damage even delicate mouldings.

the second tier of packages is placed with one end in the center of the car. Again three 1¼-inch, high-tension straps are placed around the load. This type is also a floating load that requires no bulk headings. A 40-foot car loaded this way contains about 25m feet.

There are any number of variations that may be used in loading. This is one feature that is especially good since there is no one definite way to arrange the packages in the car nor any standard size package that will work to everyone's advantage. What is best for one operator or customer may be dead wrong for another.

Cost Comparisons

Now let us see what this has cost. Figures will be based on an average production of 100,000 feet per eight-hour day, with a working crew of five men on the slick chain to pull and package the lumber as $1.70 per hour, one tally man at $2.00 per hour, one man strapping at $1.60 per hour, one fork-lift operator at $2.00 per hour, one helper at $1.60 per hour, and half the time of one carrier driver, which figures $1.00 per hour. This adds up to $133.60 for eight hours, or $1.336 per thousand. The cost of additional steel strapping and seals is $0.222 per thousand feet, or a total labor cost of $1.558 per thousand feet to package, tally, strap and load.

Fig. 5.—With the new model of the Loader, packages 2 feet wide and 16 feet long can be loaded through 6-foot doors and placed flush with the near wall.

How does this compare to the old hand-loading method previously used? The pulling from the chain into packages is the same, tallying is the same, and carrier time is the same. Our records show, over a year's period, an average car-loading time for two men hand loading all widths to be six and one quarter hours per car. The lift driver spends one hour setting lumber on the loading docks for them. This is 12½ hours total time for the loaders at $1.80 and one hour at $2.00, or a total per car load of $24.50.

With the package method and the Fowler Loader (figuring maximum time, one man strapping, one helper, and one-fork lift operator), total time is one and one half hours each per car. This gives a labor cost of $7.80 per car. The added cost of strap and seals, another $6.67, gives a total cost of $14.47 against $24.50, or a savings of $10.03 per car.

We have shown where there is a considerable savings in money. Now let us consider another savings that is just as important. In our operation we carry all our own inventory. The only way we can realize any profit on it is to get it surfaced, loaded into cars, and shipped. This, together with the fact that we do not have dry sheds to store surfaced lumber, makes it very advantageous for us to get it loaded as fast as possible. Now, instead of taking approximately six hours to hand load a car, we can load in slightly over one hour.

There is one other very important advantage. The railroads like and endorse the system because it has greatly reduced their damage claims. Needless to say, the reeciver likes it for this same reason. The Santa Fe agent at Williams requested information on our shipments from their claims department, and they reported that for a period of one year they had only one minor claim for damaged lumber. This included shipments of slightly over 500 car loads of lumber.

Smaller Packages for Single-Door Cars

The ideal type of boxcar for use with the Fowler Loader is a double-door 40- or 50-foot car. However, a check with other mill operators located throughout the country showed that this presents a serious problem in certain areas, because there is a shortage of this type of car on certain lines. This is especially true in the Northwest, where the plywood companies have first claim on cars. To solve this problem, we have developed model SD22 of the Fowler Loader. Wtih this model, the size of the package is limited to a 2 by 2 size, but it is possible to load a six-foot, single-door car in slightly over two hours.

Our experience with the two models of loaders shows that the cars can be unloaded in approximately the same time that it takes to load. From the arrival reports, we have been advised that some cars have been unloaded in 52 minutes.

The major use of the Fowler Loader at Williams has been for the benefit and welfare of the shipping company. However, as packaged lumber develops in popularity for the consumer, the loader will find its place in all phases of the lumber industry.

Discussion

Frank Varseveld (Kootenay Forest products Ltd.): If you do not bulkhead your cars, do you interlace one bundle with the next?

Mr. Fowler: We neither use bulkheads nor do we interlace, and we have had no damage claims resulting from shifting loads. Mr. Buchalter, I believe you have some reservations about the Fowler Loader. Would you care to bring them up here?

Joseph Buchalter (Weyerhaeuser Timber Co.): We feel that the loader is not adaptable enough for loading the common, narrow-door boxcar. Wide-door cars are still in short supply, and no large shipper can depend on obtaining enough of them at any given time. Further, our loading docks at Longview are 2 feet higher than the car floors. Finally, we feel that the grab and cable slings will lead to objectionable damage to uppers.

Mr. Fowler: We are working on a new model of the Loader that will work well in a 6-foot door. The grab is a standard fixture, and we have had no trouble with it. There has been some cable damage to our shops and selects, but no complaints. If this problem becomes serious, we would adopt some sort of corner block or a nylon strap, which has been tested on our selects. (*Ed. Note:* Figs. 4 and 5 show the new loader and the nylon strap, improvements put in use since presentation of this paper.)

John I. Zerbe (National Lumber Mnaufacturers Assoc.): Are there any particular problems in packaging green lumber?

Mr. Fowler: All our shipments from Haining Lumber are pine, and all go out dry.

A PROPOSED MODERN SYSTEM TO

Automate Your Lumber Handling[1]

M. H. MATER
Water Engineering
Corvallis, Oregon

Relatively simple measuring devices can sort lumber by physical dimension. Men are needed only if appearance must be judged.

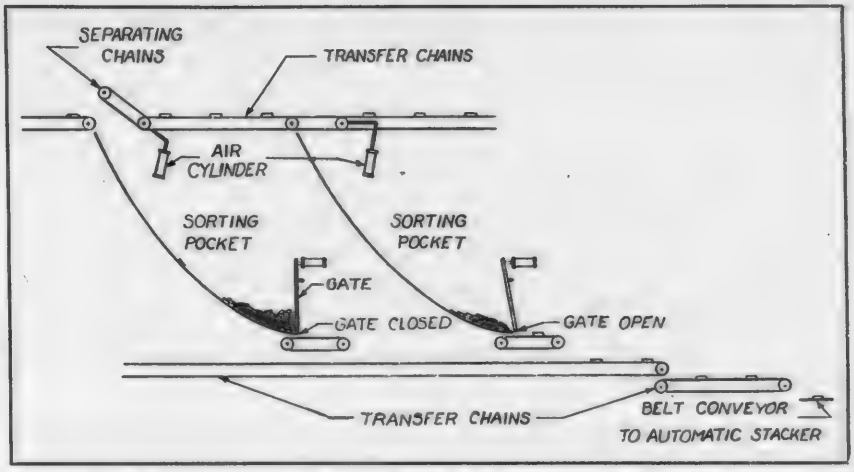

Fig. 1.—Proposed automatic sorter for a modern, automated lumber-handling system.

IN DESIGNING for automatic mechanical handling, it should be regarded as axiomatic that, wherever economically feasible and mechanically, practical, men should be replaced by machines. As a corollary to this axiom, men should be regarded as essential only in positions where judgement, based on the appearance of a piece, must be exercised. When a piece is sorted by physical dimension only, men are not required to do the sorting because simple, modern, measuring devices can be used.

While there are many pockets on a sorting table into which the pieces of lumber must fit, most of the sorts are based on physical dimensions and comparatively few of the characteristics of a piece require human judgement. In one western pine green sorter operation, for instance, pieces are graded as "common" or "shop and better". Thus there are only two sorts based on appearance. The lumber must be graded as to species, requiring a further segregation by appearance. If four species of the two grades are separated, there will be eight characteristics that must be determined by a grader. All other characteristics that go to make up the more than 60 "sorts" on the chain in this particular mill are based on physical dimensions that can be determined by measuring devices.

This analysis leads to the conclusion that, since all appearance determination is done by one man, all the other men can be replaced by suitable machines.

In this modern concept of sorting, the grader will have a grading area at the head of the chain. He sits over the chain and the pieces pass under him. The grading area is four feet long, is painted white to give contrast, has lines painted on it to give length of board, can have flippers in it to flip a board over automatically so that the grader can see both sides, and, when applicable, can have fluorescent lights shining on the board to bring out knots and pitch pockets. The grader presses a button as the piece goes by, and forgets about it; when it reaches the correct bin it automatically falls in.

Machines are on the market that segregate by dimension mechanically. There is the Setzer Sorter, for instance, and the Edge Sorter much used in the Southeast. While neither of the machines quite fills the needs of most large sawmills, both have good features that can be modified to some type of sorter like that shown in Fig. 1. The lift opening is operated by an air cylinder operated by a solenoid valve. The valve is activated by an electronic tape (not shown), which goes along the chain with the board. The tape has the length, width, and thickness of the board impressed on it by electrical measuring instruments at the beginning of the sorting table. When the valve is reached at the pocket marked to take the piece, the tape activates it and the board drops in. Tape systems of this sort are available commercially. Other similar systems are also available.

The sorting pocket, in our concept, would hold a complete kiln-car stock of approximately 9000 board feet. These boards would lie loose, like the lumber at the side of an edge sorter does. When the pocket is full, the automatic tallying device informs the grader and he routes the lumber to an empty pocket. Meanwhile, the lumber is discharged onto a chain under the sorter, which carries it to the kiln-car stacker. This concept gets away from the double handling that occurs when a stack is made at the green chain, and is then hauled to the kiln stacker and restacked.

The same concepts can be used in the rough-dry and finished sorters. The chain under the sorter would go directly to a package stacker rather than to the kiln-charge stacker.

A green-chain sorter of this type has all the flexibility, compactness, and comparatively low cost of a conventional green chain, but is mechanized by replacing men with machines, and is automated by controlling the machines with modern electrical and pneumatic devices.

[1] Presented by title at Session XIV, Lumber Manufacturing, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

The Author: Milton Mater is the head of Mater Engineering, sawmill consulting engineers, and president of Mater Machine Works, Inc., sawmill machinery manufacturers. A licensed mechanical engineer, Mater holds a BS in mechanical engineering and is chairman of the FPRS Lumber Manufacturing division.

REDUCE WOODWORKING COSTS THROUGH Methods Improvement[1]

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For maximum benefits, a methods improvement program should be built around a knowledge of methods analysis techniques and a complete understanding of the operation being studied. The most widely used analysis techniques are work simplification, operation analysis, motion economy, and predetermined time systems. Examples are presented that show original conditions and improvements based on analyses.

METHODS IMPROVEMENT reduces manufacturing costs because its application to an operation results in increased productivity. This is achieved by striving for the most economical utilization of all the human energy, materials, and equipment required to manufacture a product.

To realize maximum benefits, a methods program should be built around two components: a knowledge of methods analysis techniques and a complete understanding of the operation being studied. Without a systematic approach to the problem of determining the best method, it is rarely that job knowledge alone will uncover potential savings.

Methods Analysis Techniques

The most widely used analysis techniques are work simplification, operation analysis, motion economy, and predetermined time systems. These are similar in that they all utilize well-known methods-improvement principles, and a liberal amount of common sense. These techniques differ primarily in their depth of analysis. For example, operation analysis might indicate that a gravity-feed hopper be used to deliver the material closer to the point of use. A predetermined time system (such as Methods-Time Measurement) would consider the effect of the location and design of the hopper on the reach, grasp, and move involved in obtaining a part.

Each of the techniques studies the problem in a different minuteness of detail. This suggests that they should be used in a certain definite order. If the analyst first uses too detailed a technique, he may find himself trying to improve an operation or element that would have been eliminated by a broader approach.

Work simplication asks the following questions about the job:

1. What is done?
2. Where is it done?
3. When is it done?
4. Who does it?
5. How is it done?

The improved method is developed by a) eliminating unnecessary moves and operations, b) changing the place, sequence, or person and combining moves and operations, and, c) simplifying the necessary work by considering layout, motion pattern, tools, equipment, materials, and working conditions.

Operation analysis [2] classifies the information about the job by considering the following factors:

1. Purpose of the operation.
2. Complete list of all operations performed on the part.
3. Inspection requirements.
4. Material.
5. Materials handling.
6. Setup and tool equipment.
7. Common possibilities for job improvement.
8. Working conditions.
9. Method.

The information in each category is analyzed with the purpose of uncovering any change that would improve the present method.

The principles of motion economy are a collection of rules dealing with more effective utilization of the motions required to perform a task. The compilation by R. M. Barnes [3] is perhaps best known. Three of the 22 rules he enumerates are a) the use of smooth, continuous motions instead of those containing a sharp change of direction, b) the location of tools and materials to permit the best sequence of motions, and c) the pre-positioning of tools and materials whenever possible.

There are several predetermined time systems in use today. One of these, MTM, is defined as a procedure that analyzes a manual operation into its basic motions, and assigns to each motion a predetermined time standard dependent on the nature of the motion and the conditions under which it is made.[4] Predetermined time systems are the most detailed of the four analysis techniques mentioned in this paper.

Job Knowledge

A certain amount of technical knowledge is often necessary for obtaining a complete understanding of the job. For example, consider the problem of evaluating alternative methods for hand shaping a part. The best method cannot be determined without considering technical details such as a) direction of spindle rotation, b) wood species, c) grain direc-

[1] Presented at Session IX, Quality Control, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

The Author: George Vasiliou holds a MS degree from New York State College of Forestry at Syracuse. He was formerly employed with the Carr Industries, Inc., as an industrial engineer.

[2] Maynard, H. B. 1956. Industrial Engineering Handbook, McGraw-Hill Book Co., Inc., New York.

[3] Barnes, R. M. 1949. Motion and Time Study, John Wiley & Sons, Inc., New York, Third Edition.

[4] Karger, D. W., and F. H. Bayha. 1957. Engineered Work Measurement, Industrial Press, New York.

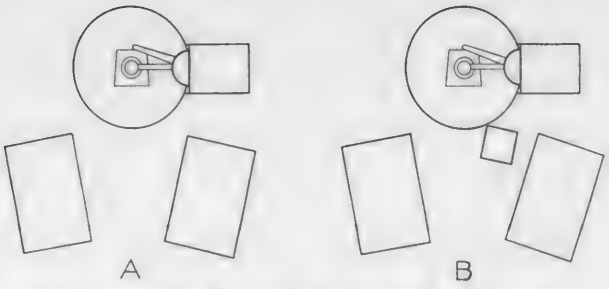


Fig. 1.—The original (A) and the improved (B) workplace arrangement for the automatic shaping of chair seats.

tion, d) possible use of holddowns and the location of the chipbreaker, and e) the effect of the cutting tool itself on feeds and speeds.

Examples of Methods Improvements

Examples will be presented by describing the original conditions and the improvements based on analysis. It will be noted that the new methods resulted from the application of methods analysis principles only, without any extensive technical knowledge being involved. The examples were purposely chosen in his manner. The most common obstacle to any methods improvement effort is the belief that the particular plant's operations are so unique that they defy improvement by any universal principles. Thus the examples illustrate that certain jobs can be improved through the use of only a relatively few basic concepts.

A paper of this length necessitates the selection of simple illustrations. This does not mean that the techniques of methods improvement are limited to uncomplicated situations. They have been successfully applied to complex problems such as plant-wide materials handling and departmental layout.

The examples illustrate how methods already in use were improved. This is usually the situation at the initiation of a methods improvement program. The long range goal of any such program, however, should be to determine the best methods prior to the start of production. It is in this respect that predetermined time systems are especially valuable.

Example One: In one shop, drawer tippers were originally cut to rough length at the swing cut-off and later trimmed to finish length at a double-end cut-off saw. The question arose as to whether the parts should be machined to the final dimension four or six at a time. Before deciding, a study was made as to the purpose of the operation. The investigation revealed that a variation in finish length of plus or minus ¼ inch was permissible. The tippers are now cut to finish length directly at the swing cut-off, thus eliminating a trimming operation and affecting a lumber savings.

This example illustrates the most important analysis principle available for cost reduction, namely to eliminate all unnecessary operations.

Example Two: Chair seats were produced at the automatic shaper, from glued-up panels, by means of a center clamp setup (Fig. 1A). The procedure for each cycle was as follows: a) Upon completing the cut, the operator removed the seats and piled them on a skid. b) He then moved to the other skid where he performed any pre-positioning of stock required. c) The panels were loaded into the shaper and the cutting cycle begun.

A study of this method reveals that some work is being preformed external to the cutting cycle that could just as well be done while the cut is being made, that is, internal of the cutting cycle. A new procedure was devised that makes use of a small stand (Fig. 1B). The new method consists of the following elements: a) At the end of the cut, the operator places the seats on the stand instead of the skid. This eliminates the time required for careful piling and also reduces transport distances. b) The operator moves to the other skid, picks up the pre-positioned stock, and loads the shaper. He then starts the cutting cycle. c) While the machine is cutting, the operator handles the seats down from the stand to the skid. He also prepositions the slabs for the next cycle, thus reducing loading time.

The analysis principle involved is that on which the well-known man-machine chart is based. Whenever the manipulation of a machine is required, the relationship of the man's activity to the process time should be investigated. Often a redistribution of the operator's work will result in a shorter over-all cycle. The same principle applies to crew or group operations. Here multiple activity charts are used to study the distribution of the work as it affects cycle time.

Example Three: A headboard post required a kerf cut as the first step in machining a notch (Fig. 2.). The kerfing was performed at the variety saw in the following manner: a) Handle one post up from a truck to the slide gage. b) Kerf the post. c) Place the post aside on the table. d) Repeat elements a, b, and c for three more posts. e) Handle four posts down to a second truck.

The operation was studied as part of a methods-improvement program. The revised method, based on multiple handling and machining, is as follows: a) Handle two posts up from the first truck to the slide gage. b) Kerf the two posts with one pass over the saw. c) Place the posts aside on the table. d) Repeat elements a, b, and c for four more posts. e) Handle six posts down to a second truck.

Multiple handling refers to moving more than one part at the same time to, at, or from the work area. Multiple processing is the machining, sanding, assembly, and so forth, of more than one part at the same time. The simple question of "can the work be handled or processed in multiples?" often leads to cost savings.

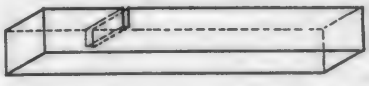


Fig. 2.—Headboard post, 12 by 1¾ by 1¾ inches, showing the kerf.

Example Four: Management suspected that automatic shaper setup time was excessively high. An all-day production study was taken. Listed below are the avoidable delays observed and the action taken to correct the situation.

Time was wasted searching for the shaper patterns required by different styles. This was eliminated by numbering the pattern rack shelfs and supplying the operator with an index that enabled him to locate any item desired quickly.

The use of the hand tools required in changing setups was characterized by unnecessary searching and a lack of adequate working space. A special setup cart was designed and built. Its main features were a) A panel on which all the required tools were placed, readily accessible for use. b) A flat area, convenient for temporarily laying down tools and materials required during any portion of the setup. c) A storage area for nuts, bolts, clamps and other items required. d) The entire unit was mounted on casters so that it could be moved close to the shaper, thus reducing reach and walk distances.

The attachment of an air clamp required several steps. A plug was first removed from one of the air lines in

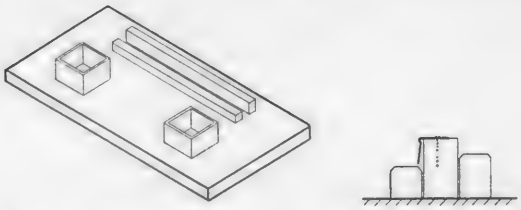


Fig. 3.—The original workplace layout for attaching no-sag "B" clips to a chair rail, illustrating the use of cleats for holding the rail, a box of clips, and a box of nails.

the shaper table and a rubber hose was screwed into the opening. The air clamp was then attached to the other end of the hose. The removal of the clamp required the same elements, in reverse order. By the use of snap-on couplings (with the male part in the shaper table) and by having the hose attached permenantly to the clamp, the time for attaching and removing clamps was drastically reduced.

This example illustrates the principle of investigating all delays to determine if they can be eliminated. Critical study of any operation will reveal delays. The problem is to determine which of these delays can be avoided by changing the method, layout, or equipment. As with any proposed change, the resultant savings must be compared to the cost of making the change to insure that the result will be a lower total cost.

Example Five: One of the operations required for a new chair was the nailing of five no-sag B" clips to a maple rail 18 by 1-7/8 by 1-1/8 inches. On the initial, small run the method used (Fig. 3) was as follows:

1. Handle one rail from a truck to the nest formed by the cleats.
2. Pick up a clip with the right hand, and a nail with the left hand. Insert nail in clip hole and insert the nail tip in the prebored rail hole. Regrasp nail and clip with left hand.
3. Pick up hammer with right hand and drive nail home. Release hammer on table.
4. Repeat elements two and three for four more clips.
5. Remove rail from nest and handle down to truck.

When the chair design sold well and larger production runs were scheduled, the operation was studied for possible methods improvements. A more efficient workplace layout was designed. Its main features are illustrated in Fig. 4. The new method is described below, accompanied by a discussion of the motion economy principles involved in its development.

1. Handle five rails up to workplace. The multiple handling principle, noted under example three, is again used to reduce handling time, primarily by eliminating a number of body movements such as turn and bend.

2. Pick up clips with both hands and transport to magnets. a) Arrange for two-handed work. Under the new method, both clips are picked up with the hands close to each other (within the area of normal vision) as opposed to picking up a nail and a clip from separate boxes. As a result, the operator can use both hands simultaneously (that is, overlap motions) to a greater extent than under the old method. b) Reduce transport distances. By having the supply of clips close to their final destination (note the location of the recess as opposed to the location of the boxes) the reaches and moves involved in this element are shorter than under the old method. c) Avoid the use of the hand to hold objects when the holding can be done more effectively by other means. The new method utilizes magnets to hold the clips in their proper relationship to the rail. This frees the hands to do more productive work. d) Work to stops whenever possible. The clips are now moved to a stop (the metal strip and the magnet) rather than having to be positioned to an exact location, as was the case under the old method.

3. Insert rail between end stops. a) The principle of working to stops is again utilized. b) Use quick-acting holding devices. The bullet-catch in one end stop provides all the pressure needed to hold the rail in place. Usually toggle clamps are the fastest clamping devices for such assembly operations, but this is one instance where a quicker sustitute was found.

4. Pick up hammer. The principle of pre-positioning tools indicated the use of the beveled cleats for the hammer nest. The latter raises the hammer handle to a convinient position, and also simplifies the grasping of the handle.

5. Pick up and insert nail in clip hole. Grasping and positioning motions are time consuming and an attempt should always be made to simplify them. a) It is easier to pick up a nail from a soft, flexible surface than from a hard surface. This is the reason for providing the nail bin with a sponge rubber bottom. b) The old method required positioning and inserting the nail to the clip hole, and then inserting the nail in the prebored rail hole. The use of magnets to hold the clip against the rail, and the elimination of the prebored rail hole, reduces the number of positioning motions required under the new method.

6. Hammer nail home.

7. Repeat elements five and six for four more clips.

8. Release hammer in nest. Here the principle of eliminating work is again utilized. Under the old method, the hammer was picked up and put down five times for each rail. This has been reduced to only one pick up and put down per rail under the new method.

9. Disengage from jig and aside to table.

10. Repeat elements two through nine for four more rails.

11. Handle five rails down to truck. Here again is principle of multiple handling.

By the old method, the clipping of one rail required 1.85 minutes. The new method resulted in a time of 1.25 minutes per rail. This represents a difference of 0.60 minute per rail, or a savings of 32 per cent of the original labor cost. In addition, the new method eliminates the preboring for nails (which required 0.10 minute per rail) and one setup of a multiple-spindle automatic borer.

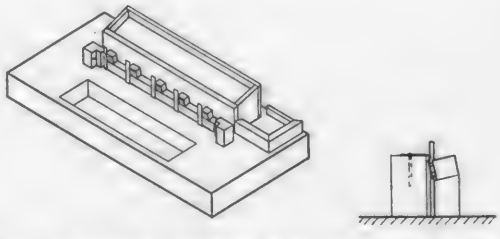


Fig. 4.—The improved workplace layout for attaching no-sag "B" clips to a chair rail, illustrating the use of magnets and stops, a bullet catch in the end stop, a recessed storage area for the clips, a bin with sponge rubber bottom for the supply of nails, and beveled cleats for prepositioning the hammer handle.

Around the World in Forest Products Research and Development

Measuring Surface Roughness With Water Drops

I. Riutaro Suzuki, *Journal of the Japan Wood Research Society* V. 4, No. 4.

In this experiment, the relation between the roughness of several sorts of cut surfaces and the contact angle of water drops on them, and the relation between the former and the tumbling angle of drops on them, were studied. Tumbling angle here means the inclining angle of test pieces when the drops of water on them start to flow down. For the purpose of giving water repellency to wood surface, the method of soaking in silicone was chosen. In this method, the concentration of silicone was 5 per cent. The following results were obtained:

1. The relation between the contact angle and the tumbling angle is given by the empirical formula:

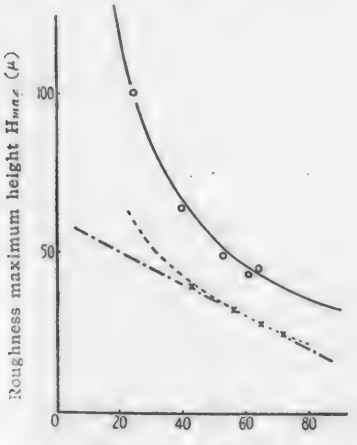
$$\theta = B - A\alpha$$

where α is the contact angle and θ is the tumbling angle.

2. The relation between the tumbling angle and the maximum height of surface roughness (H_{max}) is as shown in Fig. 7. The empirical formula is

$$H_{max} = a\theta^{l}$$

It seems that the tumbling angle is influenced not only by H_{max} but by the form of surface profile curve.



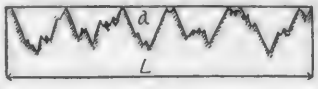
Tumbling angle (θ°)
Ripped by circular saw or mitre saw.
$H_{max}=1570\,\theta^{-0.862}$
Belt-sanded and hand-planed.
$H_{max}=1780\,\theta^{-1.000}$

Fig. 7. Relation between H_{max} and θ°

3. The relation between the tumbling angle and mean space roughness H_s (Fig. 8) is shown in Fig. 9. The empirical formula is

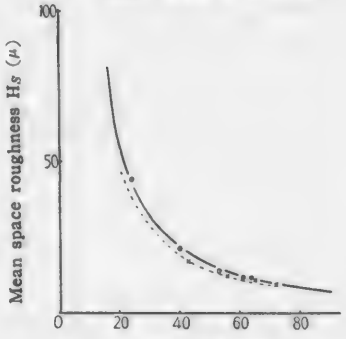
$$H_s = b\theta^{-m}$$

Apparently, the tumbling angle is strongly influenced by H_s.



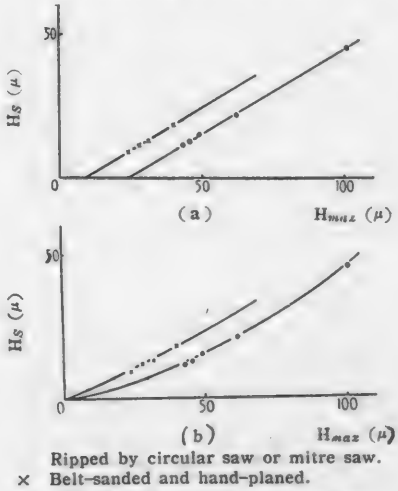
$$Hs = \frac{a}{L}$$

Fig. 8. Mean space roughness.



Tumbling angle (θ°)
Ripped by circular saw or mitre saw.
$Hs=3180\,\theta^{-1.251}$
× Belt-sanded and hand-planed.
$Hs=1610\,\theta^{-1.192}$

Fig. 9 Relation between H_S and θ.



Ripped by circular saw or mitre saw.
× Belt-sanded and hand-planed.

Fig. 10. Relation between H_S and H_{max}.

4. The relation between H_s and H_{max} is shown in Fig. 10. The empirical formula is

$$H_s = c(H_{max})^n$$

where c and n are influenced by the form of surface profile curve.

5. H_s and H_{max} were measured by the light cross section method.

Study on Pretreatment in Wood Saccharification Process. I. Pretreatment with Water. Takashi Ito and Nobuko Nakayama. *Journal of the Japan Wood Research Society* V. 4, No. 4.

Pretreatment of hardwood *(Fagus crenata* Blume) with water within the range of 140° to 260°C was studied to find its suitability for one of the wood saccharification processes. The results obtained are as follows:

1) The formation of furfural is more affected by cooking temperature than by the concentration of organic acids produced, and the maximum yield of furfural was about 50 per cent of the theoretical at 190°C.

2) Below a temperature of 210°C, the yields of residual wood decrease with the increase in time to 65 to 70 per cent of the original wood, while above about 210°C it decreases still more to 45 to 50 per cent of the wood. This decrease is due to cellulose decomposition.

3) The pentosan in the residual wood is reduced very rapidly with increasing time and pressure, and more than 90 per cent of pentosan in the original wood was removed in the 2 hours of cooking at temperature above 180°C.

It was recognized that pretreatment with water is suitable for the preparation of furfural in the wood saccharification process when the cooking temperature is about 190°C.

• Austria

Three-Country Wood Convention Planned for Vienna in 1959

A Three-Country Wood Convention will be held July 16–19, 1959, in Vienna by the Austrian Society for Wood Research, the Lignum, (Swiss Society for Wood), and the German Society for Wood Research.

The program will include papers by scientists and economists concerning automation, gluing and veneering, modern use of wood and wood materials in construction, and methods of modern wood research.

Research and Development in Furniture Manufacturing

Fount H. Rion, Jr. Vice Pres., Florida Furniture Industries, Palatka, Fla. Presented at the Florida-Georgia-Alabama Meeting, Dec. 5-6, 1957 at Daytona Beach, Fla.

Research and development have played a large part in the progress of the furniture industry. Wood utilization has been very important. The lumber percentage is the largest portion of the material dollar for a furniture manufacturer. Research on old methods of lumber care and handling have shown the industry that these practices are often costly and wasteful. Today's modern yards and kilns can easily be financed on the savings made in labor and material.

Manufacturers no longer suffer the degrade per cent that used to be taken for granted. Proper piling alignments, spacing, and covers cut degrade to a minimum. New kiln schedules are available for increased production plus less variances in moisture control against loss later in the plant.

Important to furniture plants is the use of low-quality wood as it becomes more difficult to obtain high-quality material.

With the development of particle board and its consumption by the industry, wood waste is less of a liability and is being added to the profit side of the ledger. Research in particle board is leading towards almost 100 per cent utilization of the merchantable height of standing trees. Particle board core stock is about one half the cost of solid wood core.

The adhesive and equipment manufacturers have made some of the greatest contributions toward better utilization through development of faster curing and more durable bonds. The steam presses and electronic presses are jockeying for the utmost efficiency and are improving daily. Spot welding, electronic serpintine presses, and continuous flow machines are just a few improvements of this nature.

One of the most recent developments in adhesives has been the introduction of fast-setting casein adhesives for panel to frame operations. The advantages of these adhesives are important. The speed of set lends itself to faster production with less equipment and equipment that is less costly.

Considerable progress has been made in improving the serviceability of finishes applied to wood. Wood furniture is meeting competition with metal and plastic furniture very successfully, partially due to more durable finishes. Tougher, more resistant finishes have been developed by incorporating many of the synthetic resins in the lacquer mixture. Practically pure synthetics such as urea alkyls are being used as furniture topcoats. While more satisfactory from the consumer standpoint, they create problems since the hardened resins are insoluble in ordinary solvents and repair work in production is extremely difficult. This is a research problem for the future.

Artificial graining over lacquer-base coats has allowed the use of discolored lumber and veneers. It also has created consumer acceptance of hardboard in case goods, television cabinets, and radios. The newest of these techniques is the printing of the grain on bare wood and completing the pieces with a transparent finish.

The introduction of carbide knives and saws has to a great extent reduced the expenditure of removing, replacing, and sharpening of knives and saws. Accuracy and efficiency of knives and saws were dependent in the past on the day-to-day disposition of a saw filer. The consumer acceptance of decorative plastic laminates has brought about an even greater appreciation by the furniture manufacturer for his carbide tools.

Statistical quality control is in its infancy in furniture manufacturing. Without the tool of quality control, an operation may be carried on for several days with excessive variation before discovery, resulting in loss of production time and waste of material.

Quality control charts have been used for per cent defective control and to measure defects. By the proper use of statistical quality control, savings can result in discounts on defective items delivered to a customer, loss of customer goodwill, delays in production due to manufacture of defectives at the time of major rejections, and loss of morale in the production organization.

Sandwich Construction in Prefabrication

J. D. Lincoln, Consultant, Continental Can Co., Mt. Vernon, Ohio. Presented at the Mid-West Section Meeting, Nov. 14-15, 1957 at Milwaukee.

In discussing sandwich construction for prefabrication, one usually speaks of kraft paper honeycomb. For true fireproof construction, asbestos paper can be used instead of kraft. Foam and straight honeycomb panels as core material do not have a low enough U value alone for very cold climates or for areas where air conditioning is necessary. It seems more economical, however, to fill paper core with insulation such as rock wool, fiberglass, or foam. Paper at 7¢ per pound will produce one cubic foot of honeycomb core with a compression strength of almost one hundred pounds per square inch. Foam has to weigh four to six pounds per cubic foot for equal strength, but can be obtained at 1½¢ per pound.

About 12 years ago, honeycomb houses were built in Virginia and California. One type, a small two bedroom home with living room, kitchen, dinette and bath, sold for $3,000. The house weighed one ton above the floor line, and the complete material cost with foundation, floor, electrical wiring, plumbing and heating was $740.00.

The larger house with four bedrooms, two baths, living room, dining room, and kitchen, used twice the material and had twice the floor space. It sold for $6,000.00. An interesting feature was the floor, which was made of a two-inch concrete slab poured above ground and supported by four-inch round columns on six-foot centers. The space under the slab was a plenim chamber or duct for the heating system.

The best place in which to start sandwich construction today is in partition walls. Honeycomb core can be faced with wall board banded with ¾-inch wood strips to tongue and groove edges together and to toenail top and bottom in place when setting. Outside wall panels could be faced with asbestos cement board, plywood, masonite, or any desired facing material.

It is possible to make paper honeycomb today weighing five pounds per cubic foot and capable of withstanding 1200 pounds per square inch compressive load, which is a better weight strength ratio than is possible with aluminum or fiberglass honeycomb.

The basic problem in fabrication is getting the best adhesive possible for the money available. There are many low-cost adhesives possible for use in housing. A study of the economics of honeycomb shows that it will soon be a prominent factor in partition panels and exterior panels as well as in refabrication. It can be an important factor in cutting the present cost of building.

Abstracts From Current World Literature

Insulation Board

Ziegler, R. D. A procedure for measuring the water vapor permeability of insulation board. *Tappi* 40, no. 11: 881–4 Nov., 1957).

The author describes current progress on the development of an improved method of measuring the rate of water-vapor transfer through insulation board. In this method, a specimen with a test area 12 inches square is bolted rigidly in place as a common wall between two enclosed chambers, each of which is maintained at a different R.H. by saturated salt solutions. Thus, a humidity gradient is established across the sample, and the water vapor passes from the higher-humidity chamber through the specimen to the lower-humidity chamber where it is absorbed by the salt solution. The absorbing solution is contained in four plastic dishes which can be put into the testing chamber and removed from it through a covered opening on the top. These dishes of solution are weighed, both before and after being placed in the tester, on an analytical balance which permits the weight increase to be determined to tenths of a milligram. This weight increase, correlated with the length of time the solution was in the tester, enables the rate of water-vapor transfer through the specimen to be calculated. [Bul. Pap. Chem. V. 28, No. 5]

Hardboard

Anderson, Arthur B. The chemistry of hardboards containing bark. *Norsk Skogind.* 11, no. 10: 386–9 (Oct., 1957). [In English; Norwegian summary] *cf.* B.I.P.C. 27: 32, 1367; 28: 464.

The properties of hardboards containing bark vary, depending on the nature and quantity of extractive components present. The sizing action of pinewood bark in hardboard compositions is due largely to its content of low-melting waxes. [Bul. Pap. Chem. V. 28, No. 5]

Bark Utilization

Anon. New soil builder developed from bark. *Paper Ind.* 39, no. 1: 37 (April 1957).

A method to convert ground bark into an inexpensive and unusually effective soil builder by condensation of the tannin involves addition of formaldehyde, acidification, heating, washing, and drying. The soil builder accomplishes these three things: loosens the soil and improves its moisture-holding capacity, serves as a base for fertilizer, and controls the rate at which the plants obtain their food from the soil. Experiments with the soil builder are described briefly. [Bul. Pap. Chem. V. 28, No. 5]

Wood Structure

Joranson, Philip N., Einspahr, Dean W., and van Buijtenen, J. P. A field guide to aid in recognition of natural triploid aspen. Appleton, Wis., The Institute of Paper Chemistry, Nov., 1957, 12 p.

Swedish experience with the genetic improvement of European aspen *(Populus tremula* L.) suggests that the rate of volume increment and the length of fiber tracheids might both be increased in the closely related North American quaking aspen *(P. tremuloides* Michx.) by finding or producing trees which possess a triple set, rather than the usual double set, of chromosomes. Such development and selection of tree properties might, for example, improve the strength of papers made from aspen. Studies of triploid *vs.* diploid aspen are being pursued at The Institute of Paper Chemistry. Preliminary field identification of triploids may be based on their generally greater leaf size and tree size, provided such qualities are not attributable to other genetic or environmental factors. Procedures for marking, reporting, and subsequent sampling of suspected triploids are described. [Bul. Pap. Chem. V. 28, No. 5]

Lagergren, S., Rydholm, S., and Stockman, L. Studies on the interfibre bonds of wood. Part 1: Tensile strength of wood after heating, swelling and delignification. *Svensk Paperstidn.* 60, no. 17: 632–44 (Sept. 15, 1957). [In English; Swedish and German summaries]

Techniques for studying the strength of wood under destructive conditions and for microscopical examination of the zones of failure have been developed. The dependence of tensile strength on temperature, alkali swelling, and delignification (by various pulping processes) has been determined for spruce- and birchwood. The reduction of strength by elevated temperatures is largely reversible. Strength *vs.* temperature curves of *S* shape were obtained for both wood species. The greatest strength decrease occurred in the intervals 20–70 and 120–180° C. The decrease in strength caused by swelling was greatest around 75 g./liter of sodium hydroxide. Plots of tensile strength as a function of delignification converge toward the point of defiberization at yields around 60%, whereby kraft cooks showed higher strength values than did sulfite cooks. In untreated but water-swelled wood, failure occurred either across the fiber walls or between the transition lamella and the secondary wall. The latter type of failure predominates at increased temperatures or during swelling in alkali. An additional type of failure, occurring at the middle lamella, was noticed in partially delignified wood and became predominant with increasing degree of delignification. These results are discussed in relation to energy consumption and pulp quality after defibration and beating. [Bul. Pap. Chem. V. 28, No. 4]

Construction

Bonnicksen, Leroy. Multi-Combination Pole-Type Construction. Agricultural Experiment Station, Oregon State College, Corvallis, Ore., Station Bulletin 557, Oct. 1957, 31 pp, 25¢

Report lists the features and limitations of pole-type construction, followed by illustrated discussion of types of poles, footings, 2 x 12 rafters, 24-foot trussed rafters, purlins and ties, roofing application, walls and cornices and various possible combinations. Schematic drawings of typical structures of various sizes and types are also included. The author is Assistant Agricultural Engineer at Oregon State. [BRI Abstracts, June 1958]

Molded Pulp

Anon. New uses found for molded pulp. *Pulp & Paper* 31, no. 9: 39–41 (Aug., 1957).

The expansion of the Diamond Match Co. after its merger with Gardner Board and Carton Co. is described. Since an increased demand for molded-pulp products (cartons, food containers, and "contour packages") is foreseen, new raw materials are being tested. Preliminary studies showed that excellent molded pulp can be made from 100% hardwoods; trials with sawmill slabs were encouraging. Various pretreatment methods have been tested at the Ogdensburg, N. Y. pilot plant, and the pulping of Douglas-fir, ponderosa pine, and Northern hardwoods by the new Bauerite process is being evaluated. [Bul. Pap. Chem. V. 28, No. 4]

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BRI ABSTRACTS OF BUILDING SCIENCE PUBLICATIONS, published for the use of its members, by the Building Research Institute, National Academy of Sciences—National Research Council, 2101 Constitution Avenue, Washington 25, D. C. Over 70 periodicals are reviewed, plus new books and research reports from industrial, governmental, and academic laboratories and organizations.

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiberboard and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5 per year.

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United States Plywood Corp., Brewster
The Upson Co., Lockport

OHIO
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The Kirk & Blum Mfg. Co., Cincinnati

OREGON
Brooks–Scanlon, Inc., Bend
Cascades Plywood Corporation, Lebanon
Conroy Publishing Corp., Portland
Forest Fiber Products Co., Forest Grove
Georgia–Pacific Corp., Portland
Mater Engineering, Corvallis
J. Neils Lumber Co., Portland
Oregon Lumber Co., Baker
West Coast Lumberman's Assn., Portland

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Koppers Company, Inc., Pittsburgh
Perkins Glue Co., Lansdale
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Biles Coleman Lumber Co., Omak
Cascade Lumber Co., Yakima
Columbia Plywood Co., Inc., Seattle
Chelan Box & Mfg. Co., Chelan
Diamond Match Co., Spokane
Douglas Fir Plywood Association, Tacoma
International Paper Co., Long–Bell Division, Longview
Simpson Logging Co., Shelton
Sumner Iron Works, Everett
Western Pine Mfg. Co., Spokane
Weyerhaeuser Timber Co., Tacoma

WISCONSIN
Decar Plastic Corp., Middleton
Harnischfeger Corp., Port Washington
Mosinee Paper Mills Co., Mosinee
D. J. Murray Mfg. Co., Wausau
Paine Lumber Co., Oshkosh

CANADA
B. C. Forest Products, Ltd., Vancouver
British Columbia Lbr. Mfrs. Assn., Vancouver
Canadian Forest Products Limited, New Westminster, B. C.
Dominion Electrohome Industries, Ltd., Kitchener, Ont.
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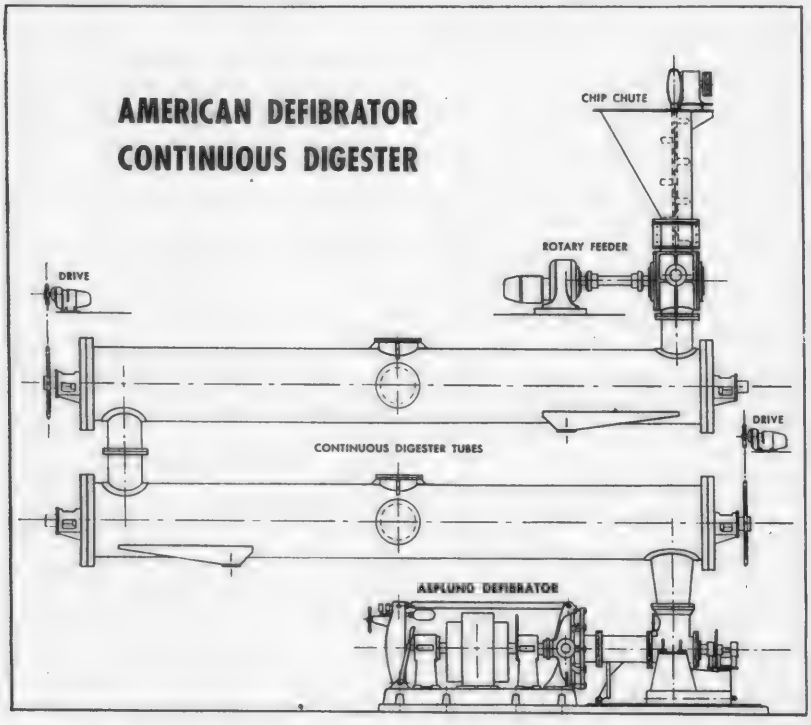


CONTINUOUS PULPING WITH AMERICAN DEFIBRATOR EQUIPMENT CONTROLS BOTH COST AND GRADE OF PULP FOR THE PAPER INDUSTRY

More and more mills are selecting American Defibrator continuous digesters and related equipment for continuous semi-chemical pulping — for economical production of controlled grades of pulp for the Paper Industry.

American Defibrator continuous digesters with Asplund Defibrators produce pulp ready for washing and secondary refining, at substantial savings in handling and power costs.

Raw materials range from hardwoods and softwoods to cotton linters and bagasse. Various cooking agents may be used, such as neutral sodium sulfite, kraft or caustic soda liquors.

Units are available with capacities from 50 to 200 tons per day.

Present use is mainly for corrugating boards, but bleachable grades now are also being produced.

AMERICAN DEFIBRATOR, INC. CHRYSLER BUILDING NEW YORK 17, N. Y. West Coast: A. H. Lundberg Mercer Island, Washington

Government, Industry, Education Confer at FPRS 12th National Meeting

LONG-RANGE RESEARCH is needed for the growth of the forest products industries. Four major speakers, representing industry, education, and government, were unanimous in this opinion, at the FPRS 12th National Meeting in Madison, June 22–27. (See full text beginning on page 97-A).

At the official opening session, June 23, V. L. Harper, Asst. Chief, U. S. Forest Service, Dr. Winton Patnode, consultant, and Dr. E. C. Jahn, N. Y. College of Forestry, addressed more than 350 persons on the topic "Insurance for the Future—Through Forest Products Research".

The future of the industry depends on research and educational programs in the forestry schools, Dr. Jahn said. "Schools can be helpful in the long-range problems of broad significance where objectivity of the highest order is needed".

In discussing government policy, Mr. Harper said: ". . . a basic tenent of our policy is to encourage universities, state agencies, and private concerns to carry on research programs, and to cooperate with them to the fullest extent. Only by such cooperation and coordination of effort can we hope to accomplish all that needs to be done."

"The forest products industry of the future will inevitably include more large units than exist today", Dr. Patnode emphasized. "Concurrently", he said, "we shall see the formation and expansion of more competent research groups, and the performance by the industry of a higher proportion of broadly applicable scientific research, leading to products now unknown and permitting hitherto unattainable improvements".

Many Sciences Underly Forest Products Research

"We must be aware of the interrelatedness of the sciences that affect wood", Dr. Patnode said. "The log is still a botanical product once it gets into the manufacturing plant. Advances in physics and chemistry of other cellular substances may be applied to ours".

"The schools must take full advantage of the resources of their university", Dr. Jahn pointed out, "particularly in the departments of biology, physics, and chemistry to make sure that diversified talent is brought to bear on research in wood".

He added that an important area for schools is to increase the productivity of labor, a role that the land-grant colleges have fulfilled for agriculture.

R. L. HILLER V. L. HARPER W. PATNODE E. C. JAHN

Roderick Carrys Through Theme at Official Luncheon

Assistant Secretary of the Army Roderick summed up the theme of the meeting in his talk at the Official Luncheon. "Basic research . . .", he said, "is truly an obligation of industry, educational institutions, and government. Without basic research our commercial and industrial complex would soon be at a standstill and would stagnate".

Mr. Roderick further cited numerous examples where basic research had aided the armed forces in solving problems, as well as aided in the development of industry.

More than 400 persons attended the luncheon, which was held June 24. Wisconsin Governor Vernon W. Thomson welcomed guests at the luncheon. The Rev. Reavis C. Sproull gave the invocation. Outgoing FPRS President Kaufert was presented with a set of luggage as a token of the Society's appreciation by incoming president W. Jeter Eason.

In his acceptance speech at the Official Luncheon, president Eason said that the Society was entering on a new era of maturity, a maturity that will present a challenge to the Society and the industry as a whole.

Dedication of FPRS Building Launches Meeting

An estimated 150 persons witnessed the dedication ceremonies of the new FPRS Office Building on Sunday, June 22. Wisconsin State Attorney General Stewart Honeck cut the ribbon.

Participating in the ceremonies were: Madison Mayor Ivan Nestingen; Dr. J. A. Hall, Director, U. S. Forest Products Laboratory; Dr. F. H. Kaufert, outgoing president; W. Jeter Eason, new FPRS President and architect of the building; Otto Heyer, U. S. Forest Products Laboratory, supervising architect; R. H. Berry, Building Fund Chairman; and R. H. Bescher, past president of the Society.

AT THE HEAD TABLE during the Official Luncheon were l. to r. W. J. Eason, Wisconsin Gov. Vernon W. Thomson, Assist. Sec. of the Army G. H. Roderick, and F. H. Kaufert.

Photo Highlights of the 12th National Meeting

A MEMBER OF THE FPRS staff, Mrs. Louise Dalton, and Bernard Granum, Nat'l Meeting Committee, registered guests at the Hotel Loraine during the meeting.

MORE THAN 400 persons attended the Official Luncheon in the Crystal Ballroom of the Hotel Loraine, Assistant Secretary of the Army Roderick spoke on the importance of wood to the armed forces and national security.

FIRST OF TWO meetings of the FPRS National Executive Board held during the week-long meeting.

SEASONING EXHIBIT at the US FPL attracted many during the tours on Thursday, June 26.

EMPLOYMENT COMMITTEE Chairman Newell Norton discussed jobs for new graduates with Dr. D. B. Richards, Alabama Polytechnic Institute.

AT THE WOMEN'S get-acquainted coffee hour were (l. to r.) Mrs. R. H. Berry, Mrs. W. J. Eason, Mrs. Fern Thompson, and serving coffee to a guest, Mrs. Ralph Simeone, chairman of the Women's Program.

FEATURED EVENT of the Women's Program was a Luncheon and Style Show held at the Rigadoon room of the Edgewater Hotel, on Lake Mendota.

MASTER OF CERENONIES F. H. Kaufert opened the dedication ceremonies of the new FPRS Executive Office Building.

GUESTS WERE INVITED to tour the interior of the $60,000 structure after it was officially dedicated.

ABOUT 150 PERSONS came inside to inspect the new office building.

R. H. Berry reported during the dedication that over $61,000 in cash, pledges, and materials had been received for the building, exceeding by $1,000 the original goal of $60,000.

Following the dedication, FPRS members and meeting registrants toured the building and were served refreshments by Mrs. Frank J. Rovsek, Mrs. Robert Hamre, and members of the FPRS staff.

Traditional Host Hour

Immediately after the dedication, registrants at the meeting proceeded to the Crystal Ballroom of the Loraine Hotel for the annual welcoming reception. D. W. Bensend, chairman of the Mid-West Section, sponsors of the event, greeted 200 registrants and their families at the reception.

AN INFORMAL GET-acquainted welcoming reception was sponsored on Sunday evening, June 22, by the Mid-West Section.

Attendance

Official attendance at the 12th National Meeting was 619, of which 69 were women. Additional non-registered attendees raised the total estimated attendance to 700.

Registration began Sunday afternoon, June 22, at 2 pm and was handled by the Madison Chamber of Commerce. The registration fee was $7 for FPRS members, $10 for non-members, and included admission to all technical sessions, division meetings, plant tours, and the Paul Bunyan Social Hour, as well as a copy of abstracts of technical papers. Ladies registration fee was $5.

HARRY D. TIEMANN (right) as he received an honorarium for his lecture on seasoning from Pat Williams, Jr., Moore Dry Kiln Co.

First FPRS Honorarium

Harry D. Tiemann, retired seasoning specialist from the U. S. Forest Products Laboratory, received an honorarium of $300 from the Moore Dry Kiln Co. for presenting a lecture on "Highlights in the Development of Kiln Drying" at the Keynote Session. The lecture was named the Charles J. Williams Memorial lecture in honor of a past president of the Moore Dry Kiln Co. The honorarium was established by the seasoning firm in cooperation with the Wood Drying Division of the Society.

R. C. DORMAN, Timber Structures, Inc., accepted the Hitchcock Award of Merit from Loren Jouett, director of marketing for Hitchcock Publishing Co., sponsor of the awards.

Award of Merit Citations

Louren Jouett, of Hitchcock Publishing Co., publishers of WOODWORKING, presented two Award of Merit Citations at the Keynote Session. The Western Pine Association and Timber Structures Inc., received the two awards. R. H. Berry accepted the award for the former.

The awards are given each year to firms and institutions who render outstanding services and contributions to the promotion of wood and wood utilization.

Judges for this year's citations were: Mr. Sorenson, president, Hammond Organ Co.; M. G. Pendelton, executive secretary, National Hardwood Lumber Assoc.; Donald Davis, president, Aetna Plywood Co.; Herbert Joseph, vice-president, Handy Mfg. Co.; and C. W. Billingsley, Fuller, Ross & Smith.

R. H. BERRY, Scott Lumber Co., accepted the Hitchcock Award of Merit for the Western Pine Assoc., from Dr. F. H. Kaufert.

Dust Control is a job for Engineers

The "rule of thumb" methods of the inexperienced, or the "engineering rules" of an experienced design, fabrication, and installation firm—which will you select for your dust control problems?

Kirk and Blum offers you . . .

ENGINEERING—a staff of qualified engineers with proven ability to solve your dust control problems.

RESEARCH—continuous research on full scale equipment, to develop the most efficient systems.

EXPERIENCE—over 50 years of dust control service to the woodworking industry.

Every Kirk & Blum installation is based on a complete service: Design — Fabrication — Installation, backed by K & B's acceptance of One Undivided Responsibility for the system to assure your satisfaction.

On your dust control problem consult Kirk and Blum, craftsmen in dust control for the woodworking industry, where fine craftsmanship is appreciated. The Kirk & Blum Manufacturing Company, 3231 Forrer St., Cincinnati 9, Ohio.

KIRK & BLUM DUST CONTROL SYSTEMS

FIRST PLACE WOOD Award Winner Howard Spalt received congratulations from J. F. Koellisch, Wood and Wood Products magazine. Looking on are (left) Dean George Garratt, Yale School of Forestry, and (right) W. R. Smith, chairman of the judging committee.

Ninth Annual Wood Awards

The 9th Annual Wood Awards, sponsored by WOOD and WOOD PRODUCTS magazine in cooperation with the Industry–Education Division of FPRS, were presented at the Official Luncheon. J. F. Koellisch, editor and manager of the magazine, presented the first-place award to Howard Spalt, Yale University. Dean George Garratt of Yale University accepted the second-place award for Robert W. Kennedy. The awards are given for outstanding research by graduate students in forestry and wood technology.

Spalt won $350 and a certificate for his paper on "The Fundamentals of Water Vapor Sorption by Wood". Mr. Spalt is currently a candidate for the degree of Doctor of Forestry at Yale University.

"Strength Retention in Woods Decayed to Small Weight Losses" was the title of the paper by Robert W. Kennedy, Vancouver, B. C., who received the second-place prize of $150 and a certificate. Currently an instructor on the faculty of forestry at the U. of British Columbia, he has completed residence requirements for the Ph. D. degree at Yale University.

Due to the high caliber of this year's entries, three papers were given honorable mention. They are: "An Electron Microscope Investigation of Pit Membrane Structure in Conifers and Hardwoods—Its Implications in the Seasoning and Preservation of Wood" by W. A. Côté, N. Y. College of Forestry; "The Strain Behavior of Wood Subjected to Repetitive Stressing in Tension Parallel to the Grain" by R. M. Kellogg, Yale School of Forestry; and "The Effect of Particle Geometry and Resin Content on the Bending Strength of Oak Flake Board" by P. W. Post, Pennsylvania State University.

A total of 13 entries were received from seven colleges and universities and were judged by Walton R. Smith, Southeastern Forest Experiment Station; Arthur L. Mottet, International Paper Co., Longview, Wash; and D. B. Richards, Alabama Polytechnic Institute.

Schools represented by the entries were: Iowa State College, Michigan State University, Oregon State College, Pennsylvania State University, State U. of N. Y. College of Forestry, U. of Minnesota, and Yale University.

U. S. Forest Products Laboratory

A major attraction of the Madison meeting was the U. S. Forest Products Laboratory. During the meeting, approximately 250 men and women attended open-house tours at the government facility. Shown during the tours were exhibits illustrating the work of the Laboratory from improved growing and harvesting to the search for new products from waste.

Registrants were also able to hold consultations with laboratory personnel on technical and economic problems. One hundred and seventy six persons used this service during the week of the meeting.

USE OF RESIDUES for particle board was illustrated by this US FPL exhibit during the scheduled tours.

Professional Society Organized at FPRS Meeting

The American Institute of Wood Engineering, a professional society for graduates of forest products curricula, was established during the recent FPRS meeting. A temporary constitution was adopted, and officers were instructed to draw up a permanent organization plan within the next two years. Because the objectives of the Society are closely related to those of FPRS, the group decided to seek means of affiliating with FPRS.

Officers elected were: J. S. Bethel, N. C. State College, president; H. O. Fleischer, U. S. Forest Products Laboratory, vice-president; R. L. Youngs, U. S. Forest Products Laboratory, secretary-treasurer; Fred Dickinson, University of California, trustee; A. Muschler, Edward Hines Lumber Co., trustee; and A. J. Panshin, Michigan State University, trustee.

Plant Tours

On the last day of the meeting, Friday, June 27, registrants were able to visit forest products facilities in Wisconsin and Illinois. Firms having open house were: Marathon Div., Rothschild; Kimberly–Clark Corp., Neenah–Menasha; Mosinee Paper Mills, Mosinee; Harnischfeger Homes,

CONSULTATION APPOINTMENTS were arranged for meeting registrants with US FPL staff by Myrtle Brugger and Wayne Lewis of the Lab.

A TYPICAL CONSULTATION that took place at the government laboratory during the meeting. Staff members are M. L. Selbo (center), and John Lutz (right).

Everything but the whispering of the leaves...

At Brewster, N. Y., is a newly opened building housing laboratories, a scientific library, and extensive facilities for testing wood and wood products. Called the Lawrence Ottinger Research Center, it is a recent addition to United States Plywood Corporation's multimillion dollar investment in creating new products for the American people and new markets for the entire wood industry. It is also the latest step in nearly 40 years of United States Plywood Corporation research and development dedicated to making our nation's timber resources good to the last chip—of utilizing "everything but the whispering of the leaves."

Over the years, the fruits of United States Plywood's development work have taken many forms . . . adhesives which have virtually eliminated delamination as a factor in plywood . . . products such as Novoply®—a wood-plastic laminate which utilizes previously unused material . . . Duraply®—with a resin-cellulose overlay which makes possible the use of second and third growth timber in marketable plywood with a superior painting surface . . . face treatments which have given fir plywood greater sales appeal and widened its markets, in products like Weldtex® and Surfwood® . . . and finishing methods which have stimulated the tremendous popularity of prefinished hardwoods. These are but a few results of research which has contributed to the health and growth of our industry and economy.

To us, America's forests whisper new challenges every day—challenges that are opportunities to grow, as our industry grows, with the nation.

UNITED STATES PLYWOOD CORPORATION

115 branch showrooms in United States and Canada

Inc., Port Washington; Allis–Chalmers Mfg. Co., Milwaukee; and Hammond Organ Co., Chicago, Ill. The Institute of Paper Chemistry, Appleton, also opened its doors to meeting registrants.

Employment Committee

The FPRS Employment Committee under the direction of Dr. Newell A. Norton, Penn. State U., was available for private interviews with persons seeking employment or employees. The service was open for a number of hours daily during the meeting. Seven persons seeking positions and representatives from two firms seeking employees were interviewed by the committee.

At the end of the meeting, Dr. Norton resigned as chairman of the committee. This ended his fourth consecutive season as employment committee chairman. In later action, the Executive Board appointed Prof. Roy C. Carter, N. C. State College, as new committee chairman.

Ladies' Program

Social highlight of the Ladies' Program was the Luncheon and Style Show at the Edgewater Hotel on Monday, June 23, followed by a tour of interesting sites in Madison.

Approximately 60 women toured the U. S. Forest Products Laboratory on Tuesday afternoon, while an excursion to the Madison zoo was held for the children. After the tour, the women proceeded to the Governor's Mansion, where they were entertained at tea.

The program ended officially on Thursday with an excursion to the Blue Mounds area that included the Blue Mounds park, Cave of the Mounds, and Little Norway.

Alumni Reunions

Following the tradition of previous years, seven schools held reunion functions during the National Meeting. They ranged from breakfasts to luncheon and dinner affairs. Schools that held reunions were: Yale U., Penn. State U., U. of Michigan, N. Y. State College of Forestry, Michigan State U., N. C. State College, and Iowa State College.

FPRS PRESIDENT EASON received the gavel of office from retiring president F. H. Kaufert.

Paul Bunyan Hour and FPRS Party

Social highlight of the week-long meeting was the Paul Bunyan Hour and FPRS Party that were held Wednesday evening at the Maple Bluff Country Club. Close to 500 persons attended these events. Entertainment was provided by the Dona Runge Water Ballet, produced by Burmek Theatrical Productions, Milwaukee. Features of the entertainment were high diving, clown diving, and rhythmic swimming.

Other Features

Division Business Meetings were held on Wednesday morning, June 25. Agendas included a resume of the year's activities, a program for the following year, and discussion of individual problems.

Other events included the Past Presidents' Dinner, the Division Officers' Advisory Committee–Executive Board Luncheon, and the Section Officers' Advisory Committee–Executive Board Luncheon.

GUESTS AT THE FPRS Party dined around the pool at the Maple Bluff Country Club. They were entertained by a water ballet. Guests unanimously agreed they would remember the chill evening.

Paul Bunyan Sponsors

The wood industry suppliers who were hosts to registrants and their families were:

Abbot Fox, Iron Mt., Mich.
Algoma Division, U. S. Plywood Corp., Algoma, Wis.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
American Cyanamid Co., New York, N. Y.
American Mfg. Co., Tacoma, Wash.
American-Marietta Co., Seattle, Wash.
Arnold Dryer Co., Milwaukee, Wis.
The Bahnson Co., Winston-Salem, N. C.
The Bauer Bros. Co., Springfield, Ohio
Behr-Manning Co., Troy, N. Y.
The Black Bros. Co., Inc., Mendota, Ill.
The Borden Co., New York, N. Y.
The Carborundum Co., Niagara Falls, N. Y.
Catalin Corp. of America, N. Y., N. Y.
The Coe Mfg. Co., Painesville, Ohio
The Connor Lumber and Land Co., Laona, Wis.
The Connor Lumber and Land Co., Wausau, Wis.
Peter Cooper Corps., Gowanda, N. Y.
Decar Plastic Corp., Middleton, Wis.
Diamond Gardner Corp., Chico, Calif.
Disston Div., H. K. Porter Co., Philadelphia, Pa.
The Dow Chemical Co., Midland, Mich.
Durez Plastics Div., Hooker Electrochemical Co., North Tonawanda, N. Y.
Fiberesin Plastics Co., Oconomowoc, Wis.
Goodman Lumber Div., Calumet & Hecla, Inc., Goodman, Wis.
Green Bay Paper & Pulp Co., Green Bay, Wis.
Edward Hines Lumber Co., Chicago, Ill.
Hitchcock Publishing Co., Wheaton, Ill.
Hough Mfg. Corp., Janesville, Wis.
INDUSTRIAL WOODWORKING, Cleworth Publ. Co., Cos Cob, Conn.
Kimberly-Clark Corp., Neenah, Wis.
Koppers Co., Inc., Pittsburgh, Pa.
The Lilly Co., High Point, N. C.
L & M Forest Products, Grand Rapids, Mich.
Masonite Corp., Chicago, Ill.
Mattison-Greenlee Service Corp., Rockford, Ill.
Mereen-Johnson Machine Co., Minneapolis, Minn.
Merritt-Solem Div., Solem Machine Co., Lockport, N. Y.
Moore Dry Kiln Co., Jacksonville, Fla.
D. J. Murray Mfg. Co., Wausau, Wis.
National Casein Co., Chicago, Ill.
National Lumber Mfrs. Assoc., Washington, D. C.
Nelsonite Chemical Products, Inc., Grand Rapids, Mich.
Nicholson Mfg. Co., Auburn, Wash.
Pacific Lumber Co., Chicago, Ill.
Paine Lumber Co., Oshkosh, Wis.
Perkins Glue Co., Lansdale, Pa.
Protection Products Mfg. Co., Kalamazoo, Mich.
Reichhold Chemicals, Inc., Charlotte, N. C.
Rhinelander Paper Co., Rhinelander, Wis.
Sherwin-Williams Co., Chicago, Ill.
Simonds Saw & Steel Co., Leominster, Mass.
Soderhamn Machine Mfg. Co., Talladega, Ala.
Solem Machine Co., Rockford, Ill.
Southern Screw Co., Statesville, N. C.
Standard Dry Kiln Co., Indianapolis, Ind.
Synvar Corp., Wilmington, Dela.
U. S. Plywood Corp., New York, N. Y.
J. W. Wells Lumber Co., Menominee, Mich.
Weyerhaeuser Timber Co., Tacoma, Wash.
Williams Patent Crusher & Pulverizer Co., St. Louis, Mo.

Record Number of Sessions Held at Madison

A. L. Mottet started the first technical session, Session I, Wood Composition Board.

Chairman of Session II, Wood Machining, Norman C. Bye introduces his first panel member.

Session IIA, Logging, was arranged (naturally) by Fred C. Simmons (standing).

Authors at Session IV, Veneer and Plywood, posed with Chairman Butler, (second from left).

C. S. Walters (writing) was chairman of Session V, Wood Preservation.

B. A. Jayne outlined a curriculum for wood technologists at Session VI, Industry-Education.

Participants in the highly successful Session VII, Helicopters in Logging, with F. C. Simmons, program chairman.

Authors at Session VIII, Glues and Gluing, with Chairman R. F. Blomquist (seated center).

Seventy five papers and two panel discussions were featured at 17 technical sessions during the 12th National Meeting in Madison. More than 80 authors and Society personnel participated. Authors at each session are shown on these two pages.

A. C. Barefoot (second from right) was program chairman for Session IX, Quality Control.

J. R. Roberts (left) arranged the program for Session X, Wood Composition Board.

John McMillen was chairman of Session XI, Wood Drying (fundamental).

Chairman of Session XI, Wood Drying (applied) was Walton R. Smith.

New Developments were featured at Session XII, Wood Finishing. Society President Eason is second from left.

The first Chemical Utilization Session, XIII, was moderated by I. A. Pearl (seated center).

Chairman Mater (standing center) with authors at Session XIV, Lumber Manufacturing.

J. A. Hall, Director, US FPL, was chairman of Session XV, Chemical Utilization (2).

First Place Wood Award winner Howard Spalt (seated second from right) presented his paper at Session XVI, General.

Ancient Miracle Material

2,365,476,967 *years*[1] before scientists combined air, coal and imagination to create our wondrous modern synthetics, a somewhat better "plastic" was developed.[2]

Among the first to recognize the unique advantages of this senior plastic was the chap at left who used it to fashion the world's first cudgel—a device then regarded as the ultimate weapon.

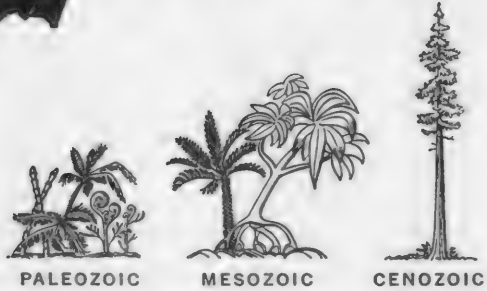
The familiarity which has diminished the novelty of this natural plastic makes it none-the-less remarkable today. For neither time nor new materials have replaced it as the planet's favorite and most versatile construction material.

The reason lies in this material's still unmatched combination of advantages. Its warm beauty defies imitation; every piece is custom made, no two are quite alike. It comes in a wide range of types, densities and sizes. Light, workable and marvelously strong, it has tremendous fatigue and impact resistance.

The basic method of producing natural polymer is quite simple. However, not inconsiderable skill and planning are required to make the process work most efficiently, as well as re-shape the basic raw material to best advantage.[3]

Of course, we do have important help. After all, the DuPonts and Monsantos make their synthetic plastics largely on their own, while our *natural* plastics industry has an excellent—and unique—supplier of semi-finished raw material.

Just like Joyce Kilmer says.[4]



[1] *Give or take a billion.*

[2] *This ancient miracle material is a natural organic ligno-cellulosic polymer, a true natural plastic commonly known as wood, composed of a complex of substances that has defied precise chemical definition.*

[3] *The basic process is called growth; the science of improving it forestry; the re-shaping is better known as forest products manufacturing.*

[4] *Surely you remember only who can make a tree.*

This is an advertisement? Indeed it is. Published on behalf of the forest "plastic" products industry by St. Paul & Tacoma Lumber Co., Tacoma, Washington, (a Subsidiary of St. Regis Paper Co.), to suggest that newness and utility are not always synonymous. Nor are promise and performance.

Minutes of FPRS Twelfth Annual Business Meeting

THE 12TH ANNUAL Business Meeting of the Forest Products Research Society was called to order by President Frank H. Kaufert, at 11:30 a.m., Tuesday, June 24, in the Main Dining Room of the Loraine Hotel, Madison, Wis. Seventy-five members were in attendance.

1. Minutes of the 1957 Business Meeting

The preceding annual business meeting was held in Buffalo, New York, June 24, 1957. The Minutes of this meeting were published in the October 1957 issue of the FOREST PRODUCTS JOURNAL. It was moved and seconded that the minutes be approved as published. The motion carried.

2. Annual Report of the Executive Secretary for 1957 Fiscal Year

Frank J. Rovsek, Executive Secretary, reported that the Society's membership and subscriptions totaled 3,653 as of January 1, 1958, compared to 3,456 on January 1, 1957, or a total increase of 197 over this period. This amounted to 5.7 per cent increase for the calendar year compared to a 14.7 per cent increase in calendar year 1956. The Society now has members in 39 countries throughout the free world in addition to the United States and Canada. During 1957, the 14 Sections held 24 separate meetings, serving principal wood utilizing areas of the United States and Canada.

Financially, the Society started the year 1957 with $14,885 in liquid reserves. The year was concluded with $11,321 of current operating funds plus $3,122 in accounts receivable. The year 1957 was a "break even" year in which total income reached $111,000 plus $3,000 in accounts receivable, and total expenditures reached almost $115,000. Including the executive office building lot, which was paid for exclusive of the current building fund raising drive, the Society reached a current net worth of $26,620 at the end of 1957.

The Executive Secretary extended his thanks to the more than 200 Section and Division Officers, committee personnel, executive office staff, and other members who have contributed to the Society's present stage of progress.

3. Report of Audit Committee

The committee consisting of John McMillen, U. S. Forest Products Laboratory; Don Brouse, U. S. Forest Products Laboratory (substituting for Ralph Simeone Fitzpatrick Lumber Co.); and H. O. Fleischer, U. S. Forest Products Laboratory, chairman; met with accountants V. C. Hobert, I. H. Guthneck and the Executive Secretary Frank J. Rovsek in Madison, June 20, 1958. The committee examined the records of the Society for the 12-month period January 1, 1957, through December 31, 1957, and reported that the summary of the financial records of the Forest Products Research Society is a true and adequate statement of financial transactions during the year ending December 31, 1957, and of the current financial condition of the Society. (For Operating Statement and Balance Sheet, see June 1958, FOREST PRODUCTS JOURNAL).

The accounts do not include money contributed to the National Building Fund Committee and retained in the hands of the committee chairman pending completion of the campaign.

The Audit Committee commended the Executive Secretary, Mrs. Dalton, and Mr. Guthneck and Mr. Hobert for the excellent condition of the financial records.

The committee recommended 1) that payments to sections be adjusted as indicated in Mr. Guthneck's report at the time when the next payments are made; 2) that petty cash disbursements from now on be transferred by journal entries to the accounts benefited whenever the petty cash fund is replenished, or at the end of the calendar year; 3) that a new inventory be made of all substantial equipment and furniture items when the move is made to the new office building. (Card records should be set up for each item, providing a complete description, date of purchase, and original cost or value. Minor items should be considered expendable and not carried on inventory.); 4) that a final financial statement be secured from the Chairman of the National Building Fund, to include a statement of materials donated, their value, and the names of the donors; 5) that complete financial reports be secured annually from all sections.

4. Report of 12th National Meeting Committee

Robert L. Hiller, General Chairman, reported that the total registration at the meeting to date was approximately 500 including 70 ladies. He said the Official Luncheon was sold out at 430 places, but that tickets for the FPRS

FPRS SECTION MEETINGS AUGUST 1, 1957 TO JUNE 1, 1958

Date	Section	Place	Attendance	Subject
Aug. 15–17, 1957	Upper Miss. Valley	Int'l Falls, Minn.	100	Fibreboard Products, Hardboard
Sept. 27–28, 1957	Inland Empire	Omak, Wash.	.....	Improving utilization at sawmills
Oct. 7–8, 1957	Pacific Northwest	Portland, Ore.	.....	End and Edge Gluing of Wood Products
Oct. 11, 1957	Great Lakes	Holland, Mich.	100	Plywood Warpage Clinic
Oct. 17–18, 1957	Ohio Valley	New Albany, Ind.	50	Finishing, Packing & Sanding Veneer Products
Oct. 21–22, 1957	Mid-South	Crossett, Ark.	.....	The Forest & The Products
Oct. 25, 1957	Northern Calif.	Ukiah, Calif.	.....	.....
Oct. 31–Nov. 1, 1957	Carolinas–Chesapeake	Roanoke, Va.	80	Gluing, Logging & Drying
Oct. 31–Nov. 1, 1957	Northeast	New York City, N. Y.	88	Imported Woods—Modifying Wood for Use & Handling of Wood
Nov. 8, 1957	Rocky Mountain	Denver, Colo.	40	Waste Wood Utilization
Nov. 14–15, 1957	Midwest	Milwaukee, Wis.	57	Wood in Home Construction
Dec. 5–6, 1957	Fla.–Ga.–Alabama	Daytona Beach, Fla.	.....	Progress Reports on Research and Developments in Wood Utilization
Jan. 20–21, 1958	Pacific Northwest	Corvallis, Ore.	150	Marketing of Forest Products
Feb. 22, 1957	Rocky Mountain	Ft. Collins, Colo.	.....	Research in Wood Utilization
Mar. 5, 1958	Pacific Southwest	Los Angeles, Calif.	.....	.....
Mar. 30–31, Apr. 1, 1958	Jt. Northeast–Eastern Canadian, with ASME	Syracuse, N. Y.	160	Applied Research in Wood Products
Apr. 15–16, 1958	Jt. Inland Empire—N. W. Wood Products Clinic	Spokane, Wash.	140	Wood Waste Utilization
Apr. 17–18, 1958	Ohio Valley	Batesville, Ind.	.....	Woodworking Problems
May 1–2, 1958	Northern California	Berkeley, Calif.	.....	Finishing & Bark Utilization
May 5–6, 1958	Pacific Northwest	Seattle, Wash.	150	Marketing of Forest Products
May 8, 1958	Pacific Southwest	Los Angeles, Calif.	.....	.....
May 12, 1958	Upper Miss. Valley	St. Paul, Minn.	.....	.....
May 15–16, 1958	Fla.–Ga.–Ala.	Macon, Ga.	.....	Pallet Manufacture & Modern Sawmills

For FAST, EFFICIENT DRYING *of*

VARIOUS WOOD PRODUCTS, VENEERS & FIBRE BOARDS

8 Line Gas Fired Coe Fibreboard Dryer

Wet end 10 section, 4 line, 12 ft. roll Model 48 Coe Veneer Dryer.

Industry Depends Principally Upon

COE DRYERS

Since the first Coe continuous dryer was built and sold in 1902 the design, construction and efficiency of these machines have been consistently improved.

Machines are now available in various types and sizes for drying fibreboard and veneer for many purposes including plywood.

Coe Dryers are conservatively rated and sold on a **guaranteed performance basis.** Almost without exception, performance has exceeded the guarantee.

Our engineering and research departments are always willing and anxious to cooperate in the development of drying processes for new wood products.

The COE MANUFACTURING CO.
PAINESVILLE, OHIO

Party on Wednesday evening were still available. He felt the meeting would be successful both from the standpoint of attendance and finances.

5. Report of the Executive Office Building Fund Committee

Raymond H. Berry, Chairman of the committee, announced that the Building Fund Program had reached a grand total as of the meeting of $61,-891.60 towards the goal originally established at $60,000. The present committee accounted for a total of $50,292.87 of the amount since the opening of the official campaign on April 15, 1957. The balance represents contributions in the form of cash received since the inception of the Building Program and held in reserve.

President Kaufert commended Mr. Berry, Mr. Eason, the designer of the building, and the many persons who participated in the fund-raising program.

6. Report of the National Membership Committee

Tony Veazey, National Membership Chairman, noted that the present membership has reached 3,741 as compared with 3,618 as of June 1, 1957. He reported that 12 representatives of the National Membership Committee met earlier at the meeting and adopted a program of action for the forthcoming year which will operate at the Section level. The committee plans to prepare thorough lists of principal wood industries in each state of the U. S. and Canadian provinces which will be submitted to the Sections for screening and followup work.

He also announced the Society's acquisition of two new Supporting Members, Decar Plastic Corp., Middleton Wis., and Timber Products Chemical Co., Minneapolis, Minn.

7. Report of the Publications Committee

Chairman E. G. Locke reported that the committee met on Monday evening, July 23, with excellent attendance. He stated that there were no major publication problems at present and that the committee was gratified to note that the backlog of unpublished papers has been reduced to a practical level.

The committee reported that a statement of publication policy had not yet been prepared and felt that such a statement would be useful. The committee also recommended that when one field is featured in an issue of the JOURNAL, no more than 50 per cent of the issue should be devoted to the feature.

8. Report of the Editor

Robert H. Hamre, Editor, reported that 71 articles have been published in the first six issues of 1958, compared to 60 in the same period in 1957. A total of 998 articles has now been published since the first issue of the JOURNAL in 1951. So far this year, the total number of pages published is just 4 below last year's 460 after 6 issues, but 295 pages of articles have been published compared to last year's 266 at this time.

He reported that, as of the June 1958 issue, the JOURNAL is now back on its originally scheduled mailing date of the 15th of publication month. He stated that at present there is approximately an 8-month backlog of articles compared to a 10-month backlog at the time of the 1957 National Meeting and a 1-year backlog at the time of the 1956 National Meeting.

As of 6/16/58 there were 127 papers on hand compared to 160 papers on hand at the same time last year. Of these, 56 are Section or Regional papers, 23 National Meeting papers, 31 contributed papers, and 17 Wood Award Entries. Of the 127, 10 are to be abstracted, leaving 117 papers under consideration. The 23 National Meeting papers include one from the 1957 meeting, while the rest are from the 1958 meeting. We expect however, he said, to receive more than 60 additional National Meeting papers during the next few weeks.

The cumulative index for 1958 will be published in the December issue, and the February 1959 "Annual Review" issue will again contain reports of developments in the past year in the various segments of the industry.

Because the backlog sometimes creates a situation where a paper is published as long as a year after it is submitted, the date a contributed paper is received is now indicated by a footnote when the paper is published. A footnote indicating the date of presentation of National and Section papers has been standard practice.

A WELL ATTENDED meeting was held by the Publications Committee at the National Meeting.

The present aim of the editorial office is to reduce the backlog to about a six-month supply during the next year and then maintain the backlog at that level.

9. Report of the Resolutions Committee

1) The Society records with deep regret the passing during the past year of the following members: J. J. Egan, A. Walter Lewis, G. Hodges Bryant, Victor J. Kraus, George R. Curtis, E. R. Martell, E. J. Fishbaugh, Harold V. St. Clair, Thomas D. Perry, A. H. Marten, G. E. Chamberlain, and Norvelle G. Hundley.

Be it resolved that this expression of sympathy to the families and friends of these members be included in the permanent records of this meeting and of the Society.

2) In appreciation of the meritorious services that have been rendered to the FPRS during their term of office,

Be it resolved that the gratitude of the Society be extended to all of our outgoing officers including Executive Officers, Regional Board Members, and Section and Division Officers.

3) Recognizing that the success of the 12th Annual Meeting of the Society is in a large measure due to the foresight, planning, and diligence of the annual meeting committees,

Be it resolved that the Society hereby acknowledge its appreciation to the members for their excellent and successful work.

4) In view of the splendid cooperation and services provided by our host hotels in helping to make this Annual Meeting a success,

Be it resolved that the appreciation of the Society be extended to the management and staff.

5) Recognizing the contributions that the 60 Paul Bunyan Hour Spon-

sors have made to the social portion of our meeting,

Be it resolved that the Society extend its appreciation to the sponsoring companies and organizations.

6) In appreciation of the excellent cooperation given to the Society by the State of Wisconsin, City of Madison, The U. S. Forest Products Laboratory, and the various other institutions and plants that have opened their doors to the members and guests of the Society,

Be it resolved that the gratitude of the Society be extended to the organizations and to each individual who has contributed to make the 12th Annual Meeting one of the outstanding meetings in the history of the Society.

7) A goal in the growth of the Society has been realized during the past year with the dedication of the new Executive Office Building in Madison, Wisconsin.

Be it resolved that the gratitude of the Society be extended to each and every contributor and to everyone who has worked to achieve this objective.

10. Report of the Tellers Committee

Chairman of the Committee, Harold Evans, reported that the Tellers' Committee met on the previous evening and opened and counted the ballots. He reported that the following persons were elected to office: President-Elect, E. S. Harrar; Vice-President, R. H. Berry; North Central Regional Board Member, J. J. Allegretti; South West Regional Board Member, F. E. Dickinson.

Elected to the National Nominating Committee were: A. A. Marra, R. F. DeGrace, L. A. Patronsky and L. N. Erickson.

11. Report of the American Institute of Wood Engineering

James S. Bethel read a statement of the newly formed organization of the American Institute of Wood Engineering at the business meeting. The statement follows:

"Among the technically trained members of the Forest Products Research Society, those who are graduates of forest products curricula currently have no professional affiliation. Accordingly, a group of such Forest Products Research Society members met on Sunday, June 22, and established the nucleus of a professional society with the tentative title of "American Institute of Wood Engineering".

"A temporary constitution was adopted for the group. The elected officers were instructed to evaluate this tentative constitution and draw up a plan for a permanent organization within the next 2 years.

"Because the objectives of the group are closely related to those of the Forest Products Research Society, the officers were specifically instructed to seek means of affiliating the group with FPRS for the mutual benefit of both organizations.

"Signed for the American Institute of Wood Engineering. James S. Bethel, President; H. O. Fleischer, Vice President; R. L. Youngs, Secretary-Treasurer; Fred Dickinson, Trustee, A. Muschler, Trustee, A. Panshin, Trustee."

12. President Kaufert announced that new officers of the Society would be formally introduced at the Official Luncheon, and that gratitude for service of the outgoing board members would be acknowledged simultaneously. President Kaufert declared the meeting adjourned at 12 noon.

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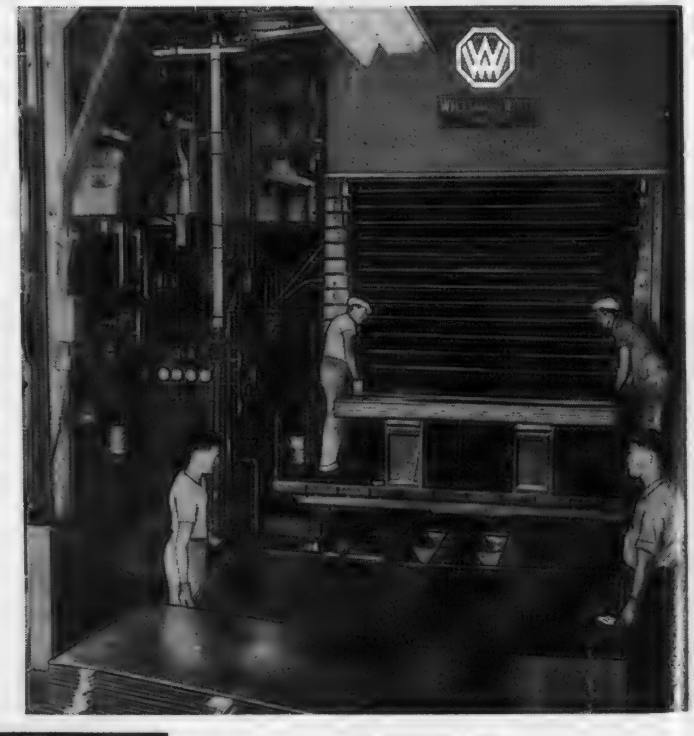

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FPRS Sections Move Toward Uniform By-Laws

FOR THE NINTH consecutive year, members of the National Executive Board met with Section Officers and their delegates during the annual meeting. The gathering took place at a luncheon on June 25, at the Loraine Hotel.

A major recommendation of the Section Officers Council was that abstracts or condensations of up to one-half page be run, in addition to the complete technical articles in the FOREST PRODUCTS JOURNAL to summarize the conclusions and practical aspects for those who do not have the time or background to digest the entire paper.

An important area of discussion was about the adoption of uniform by-laws for all 14 Sections. The Section Officers reported that six Sections had adopted by-laws in conformance with National requirements.

THE SECTION OFFICERS-Executive Board Luncheon was held on June 25 during the Nat'l meeting. An important area of discussion was the adoption of uniform by-laws.

1. President W. J. Eason called the meeting to order at 1 pm.

2. After introduction of representatives present, Mr. Eason turned the meeting over to the acting chairman of the Section Officers' Advisory Committee, Dr. Eric A. Anderson, Chairman of the Northeast Section.

3. The Sections reported progress on adoption of uniform by-laws to conform with those of the National Society. It was reported that the Pacific Southwest, Mid-South, Northern California, Pacific Northwest, Florida–Georgia–Alabama, and Carolinas–Chesapeake Sections had adopted uniform by-laws. The Northeast and Mid-West Section have by-law committees working toward uniform by-laws, and the Upper Mississippi Valley Section will vote on revised by-laws at their Fall meeting.

It was voted that the national office furnish the Sections with an up-to-date status report of by-laws by August 1. Included in the report were to be variations from the standard by-laws.

4. A brief discussion of the procedures in returning papers not suited for publication in the FOREST PRODUCTS JOURNAL was held. The policy of the Society is to return papers originally submitted at Section meetings to the Section Chairman. The Sections indicated that they would like in all cases, to have a stated reason for rejection that they could in turn pass along to the author. It was also recommended that Section V of "How to Write for FPRS" should be clarified to define the responsibility of the Sections both with regard to submission of papers to the Executive Office and with regard to getting the permission of the author before submission.

5. It was recommended that the executive office send to the chairman of each Section a sufficient number of copies of "How to Write for FPRS" for distribution to potential authors.

6. A discussion was held on the technical level of JOURNAL papers. The policy of the Society to maintain a balance of 50 per cent of non-technical and semi-technical papers, along with 50 per cent technical papers in the average issue was discussed. The Section Officers stated recognition that there was a need for a wide range of material to appear in the JOURNAL.

It was recommended that abstracts of one-half page be included with technical articles to summarize the conclusions and practical aspects for those who do not have the time or the background to digest the entire paper. It was felt that these abstracts could then easily be reprinted by extension departments to place before industry, papers of immediate interest.

7. The committee recommended that the National Office contact all Sections and urge them to set up machinery for distribution of the FPRS–NLMA career brochures. It was recomended that the National Office furnish the National Lumber Manufacturers Assoc. with names and addresses of all Section officers as an indication of the willingness of the Society to help in the distribution. The Executive Board will discuss this recommendation at its Fall meeting, and report to the Section Chairmen at that time.

8. The committee recommended that the National Board consider a change in the scope of the Wood Award program so that one Award would be made for students working toward their Ph.D., and one Award for graduate work up to and including the Masters Degree. The meeting voted that this recommendation be referred to the Industry–Education Division for its consideration, and that the committee advise the Executive Board of its feelings in the matter for action at the Board's Fall meeting.

9. The meeting was officially concluded at 1:30 p.m.

Those attending the meeting were: James Bethel, Carolinas–Chesapeake; M. A. Taras, Carolinas–Chesapeake; William Hopkins, Mid-South; John Howe, Inland Empire; V. W. Cothren, Mid-South; W. F. Lakamp, Ohio Valley; H. A. Espel, Ohio Valley; J. Allan Hauter, Northeast; B. A. Jayne, Northeast; H. E. Troxell, Rocky Mountain; John H. Syme, Pacific Northwest; A. L. Long, Northern California; G. S. Billington, Eastern Canadian; W. A. Kluender, Mid-West; C. R. Batten, Upper Mississippi Valley; J. A. Doyle, Eastern Canadian; R. H. Bescher, Northeast; D. W. Bensend, Mid-West; H. J. Gill, Jr., Mid-West; Paul Lane, Upper Mississippi Valley; W. B. Wallin, Upper Mississippi Valley; Eric A. Anderson, Northeast; Perry Acuff, Pacific Southwest; R. H. Hamre, National Office; Edward G. Locke, Mid-West; W. L. Irwin, Carolinas–Chesapeake; D. K. Saunders, Northeast; J. J. Allegretti, Mid-West; Tony Veazey, Inland Empire; F. E. Dickinson, Pacific Southwest; F. H. Kaufert, Upper Mississippi Valley; W. Jeter Eason, Mid-South; Raymond Berry, Pacific Southwest; F. J. Rovsek, National Office.

Division Interest Survey to be Continued

FOLLOW-UP QUESTIONNAIRES to determine Division interest were recommended by officers at the Division Officers-Executive Board Luncheon.

THE SECOND ANNUAL Luncheon Meeting of members of the National Executive Board and the Division Officers' Advisory Committee was held during the 12th National Meeting June 26, in the Loraine Hotel.

Again of interest this year was the division preference questionnaire sent to the membership during the past year. Discussion was held on the feasibility of follow-up questionnaires for members who had not replied to the first mailing.

1. President Eason called the meeting to order at 1 p.m. He introduced the new Division coordinator, R. H. Berry, who is responsible for all Division activities with the exception of the National Meeting Program. He also introduced the previous coordinator, E. S. Harrar, who as President-Elect of the Society now assumes responsibility for the technical program at the 1959 National Meeting.

2. Mr. Berry addressed the meeting and described the structure of the Society as organized horizontally by the 14 Sections and vertically by the 14 Divisions. He indicated that it would be his intention in the forthcoming year to develop ways and means for closer cooperation between the Divisions and Sections.

3. Dr. E. S. Harrar, Chairman of this year's Division Officers Advisory Committee, presented the recommendations of the committee.

a. The committee recommended that follow-up questionnaires be sent to members not replying to the first in order to increase coverage of the membership.

b. The committee wanted to know the possibilities of obtaining statements of Division preference from new members at the time of application for membership, and from old members on a continuing basis at the time invoices for annual dues are mailed.

c. The committee recommended that the Executive Board provide for a clear and simple chain of authority and responsibility with regard to annual meeting technical program planning, and further that the Executive Board designate the proper officer for the program chairman to correspond with regarding the program. The committee pointed out that Division and Program Chairmen commonly had to correspond with as many as four people concerning the same subject matter.

d. The committee recommended that early in the Fall and for several successive months, the JOURNAL include an invitation to members to submit proposals for papers for presentation at the annual meeting, the invitation to include a request for title and outline of the proposed paper, and indicate what technical sessions are to be held.

e. The committee recommended that an over-all theme for the next National Meeting be decided upon by the General Program Chairman and the President-Elect. It was suggested that at the Division level an attempt might be made to have at least one paper in each session that reflected the theme, but this should not be so rigorously applied that it prevented program chairmen from scheduling the best research papers available.

f. It was the sense of the Division Officers closed meeting that recent actions of the Executive Board had made Division operations easier, and that the Executive Officers and staff had been very helpful to Division Officers in the conduct of their offices.

4. Milton H. Mater requested the names of those FPRS members who indicated their second choice of preference to be the work of the Lumber Manufacturing Division. It was agreed that the Executive Office would supply this information at an early date.

5. Mr. Mater discussed the long-range potential that the Society might ear-mark some funds to help underwrite necessary fundamental research. He described a current project of his Division, outlining one hundred areas in which research is needed in lumber manufacture.

6. The following Divisions indicated plans to arrange technical sessions for the San Francisco meeting: Glues & Gluing; Wood Finishing (two meetings, one on new processes and materials); Chemical Utilization (two sessions, one a technical symposium and one on general chemical utilization) Wood Machining; Lumber Manufacturing; Wood Drying (possibly a second session in conjunction with the Lumber Manufacturing Division); Wood Preservation (will cover fire retardant treatments); Packaging; Quality Control; Logging; Industry-Education; Veneers and Plywood and Merchandising.

7. A discussion was held on providing for rotation of Division Officers. It seemed desirable that periodic rotation take place. It was stated that the Divisions may recommend successor chairmen and other officers for the final approval of the President of the Society.

8. Discussion was held on the need to develop the status and objectives of Society by-laws. At their Fall meeting, the Executive Board will discuss the desirability of establishing Division by-laws and will report back to the Divisions.

9. The meeting was adjourned at 1:30 p.m.

Those who attended the meeting were: F. H. Kaufert; D. G. Lubeck, Wood Finishing; D. F. Laughnan, Wood Finishing; F. E. Dickinson; J. M. McMillen, Wood Drying; R. F. Blomquist, Glues & Gluing; W. R. Smith, Wood Drying; A. R. Tegge, Packaging; J. S. Bethel, Industry-Education; H. I. Winer, Lumber Manufacturing; N. E. Bye, Wood Machining; M. H. Mater, Lumber Manufacturing; J. A. Doyle, Logging; I. A. Pearl, Chemical Utilization; A. H. Bishop, Wood Preservation; A. S. Gregory, Chemical Utilization; D. K. Saunders; W. L. Irwin; J. J. Allegretti; R. H. Hamre; Tony Veazey; W. J. Eason; R. H. Berry E. S. Harrar; and F. J. Rovsek.

CHEMICAL UTILIZATION DIVISION

GLUES AND GLUING DIVISION

Minutes of 1958 Division Business Meetings

Chemical Utilization Division Plans Annual "Memorial" Lecture

A. S. Gregory, Chairman, Weyerhaeuser Timber Co., Longview, Wash.

I. I. A. Pearl, vice-chairman of the Division, presented a report on the two sessions presented by the Division at the National Meeting.

II. Report of Sub-committee covering Ojective, Scope, Functions, and Methods of the Division.

E. G. Locke read the report drawn up by Locke, Gregory and Pearl, which follows:

Objective: The Division objective is the full exploitation of the chemical approach as a means of better and more complete utilization of the raw materials produced from the forest.

Scope: The primary emphasis of the Division is on utilization. Its activities are complementary to those of organizations such as the American Chemical Society where basic, scientific research on the nature and behavior of matter has long been reported, and to organizations such as TAPPI, which specialize in covering the field of pulping of wood.

Functions: To a) collect, interpret, and disseminate information on progress being made here and abroad in new methods and improvements in old methods for chemical utilization of forest products; b) encourage, promote, and support fundamental research and development work on the nature of the forest raw materials and methods by which they can be chemically utilized; c) coordinate activities with those of other professional societies with related interests; d) acquaint FPRS membership with the accomplishments and publications of other professional societies; e) interpret the significance of new research findings as they may relate to chemical utilization; and f) bring together in FPRS and encourage exchange of information between those individuals with interests in the chemical utilization of wood.

Methods: Specific methods for accomplishing the functions of the Division must be on a realistic basis which will take into consideration the amount of time individuals involved have available for such activities.

1. Arrange technical symposia on specific fields of chemical utilization and general sessions to be presented at national meetings.

2. Prepare and publish an annual review of chemical utilization in the Society JOURNAL, enlisting the cooperation of specialists in the various fields.

3. Strive to establish an Annual Memorial Lecture on chemical utilization, each lecture being on a specific field. This will include arranging for financial support (a fixed award in range of $500 is envisioned).

4. Prepare news releases on important chemical utilization developments to be released through the national office of the Society.

5. Contact chairmen of similar divisions of other technical societies (including TAPPI, Cellulose and Carbohydrate Division ACS, AIChE, and CPPA) to learn of their current and planned programs, acquaint them with our plans, and advise our program committee.

6. Compile, maintain, and distribute a list of institutions and companies active in the field of chemical utilization (excluding conventional cellulosic pulp and its derived products). This list is to include general nature of activity and individuals responsible for these programs.

III. Discussion of the Report.

Fred Meyer proposed that the Division concentrate only on new information and not spend time on reviews. After considerable discussion, the group agreed that reviews were needed and were an important function of the Division. Objective and scope and all other functions were accepted by the membership.

Chairman Gregory discussed the needs for committees within the Division to carry on the separate functions and the need for voluntary help from the Division membership to aid the appointed chairmen of each committee. The Methods were then discussed by the membership in order of their appearance in the report.

1. Arranging of technical symposia for national meetings is the duty of the Program Committee, E. G. Locke, Chairman.

2. The annual review was thought to be an important contribution of the Division in the past. A. S. Gregory is chairman of the Annual Review Committee.

3. There was some disagreement as to the type of lecturer desired for an annual memorial lecture on chemical utilization. Some desired a mature expert and others a graduate student. It was agreed that a committee should consider the matter. Frederick Perry was appointed chairman of the Memorial Lecture Committee.

4. J. F. Saeman was appointed Chairman of the News Release Committee.

5. The fifth method falls within the activity of the Program Committee.

6. It was noted by Dr. Schwartz that the FAO had compiled such a list as the Division contemplated, and it was agreed that the list be checked by I. A. Pearl, Chairman, Chemical Utilization Directory Committee.

7. Reavis Sproull was reappointed Chairman, Bibliography Committee.

IV. Report of the Nominating Committee.

J. F. Saeman, reporting for the Nominating Committee (Saeman, A. W. Goos, and K. G. Chesley), recommended that the same officers be retained for another year. It was so moved by E. G. Locke, seconded by Reavis Sproull, and passed unanimously.

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V. Officers for 1958–1959.

Chairman: A. S. Gregory, Weyerhaeuser Timber Co.; Vice-Chairman: I. A. Pearl, The Institute of Paper Chemistry; and Secretary: F. G. Perry, Arthur D. Little, Inc.

The meeting was adjourned.

VI. Attendance.

Attending the Chemical Utilization Division business meeting were: J. F. Saeman, U. S. Forest Products Lab.; Fred J. Meyer, Dow Chemical Co.; Reavis C. Sproull, Philip Morris, Inc.; Walter H. Koepp, Michigan College of Mining and Technology; Franklin W. Herrick, Rayonier, Inc.; T. I. Briggs, Alaska Pine & Cellulose, Ltd.; E. G. Locke, U. S. Forest Products Lab.; I. A. Pearl, The Institute of Paper Chemistry; A. S. Gregory, Weyerhaeuser Timber Co.; B. A. Jayne, Yale School of Forestry; E. C. Jahn, State U. of N. Y. College of Forestry; Carter Watson, Puget Sound Pulp and Timber Co.; J. M. Sayward, Norwich University; C. B. Hemming, U. S. Plywood Corp.; Mitsugu Yoshimura, Yale University; G. B. Walker, Jr., Proctor & Gamble Co.; W. L. Meek, M. & O. Paper Co.; H. Schwartz, Canadian Forest Products Lab., Ottawa; D. Stranks, Canadian Forest Products Lab., Ottawa; F. G. Perry, Jr., Arthur D. Little, Inc.; and J. A. Hauter, Allan Products Co.

Gluing Division to Propose By-Laws for Operations

R. F. Blomquist, Chairman, U. S. Forest Products Laboratory, Madison, Wis.

The meeting was called to order at 10:00 a.m., June 25, 1958. Chairman Blomquist reported on the Division interest survey, which indicated the Glues and Gluing Division had 227 members, making it second only to the Composition Board Division.

I. 1959 Technical Sessions.

Chairman Blomquist opened discussion on technical sessions for the following year. It was suggested by M. L. Selbo that fewer technical papers be presented to allow more time for discussion. W. P. Clark suggested that preprints of papers be made available with the actual presentation of an abstracted form, thus leaving time for discussion. Chairman Blomquist pointed out that preprints presented a problem because of the cost. Suggestions were that authors be encouraged to supply preprints on their own. An alternative suggestion was that tables or important figures be preprinted so that members could have important data immediately and escape the time lag between presentation and publication.

Several members discussed the possibility of reproducing a limited number of copies of papers or the preparation of tables and abstracts for ditto or similar reproduction methods.

The group voted to limit the number of papers to three or four in order to permit full presentation and adequate discussion. It was also voted that the Glues and Gluing Session be allowed more time next year. It was voted to have a technical session at the San Francisco meeting in 1959. An evening discussion was suggested.

II. Discussion on Theme for the San Francisco Meeting.

Chairman Blomquist mentioned that the theme for the next National Meeting should be broad in scope and not regional. It was suggested by one member that a theme might stifle spontaneity.

Subjects suggested for coverage at the next meeting were: lead to wood; copper to wood; contact cements and other special adhesives; a team paper between a contact glue producer and successful industrial user; end-jointing; high frequency curing and electrode design; new test methods; and long term durability data.

M. L. Selbo suggested that "rehash" papers not be included in the program.

III. Division Representatives in the Sections.

Chairman Blomquist suggested that a gluing division representative should be active in each Section.

IV. By-Laws.

Chairman Blomquist opened discussion on the need for a set of by-laws to clarify the duties and the tenure of the officers.

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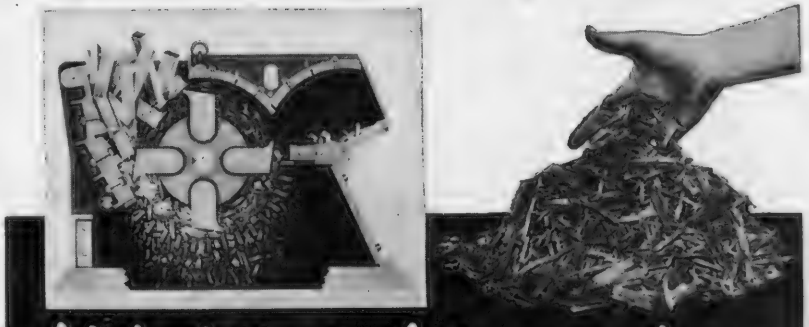

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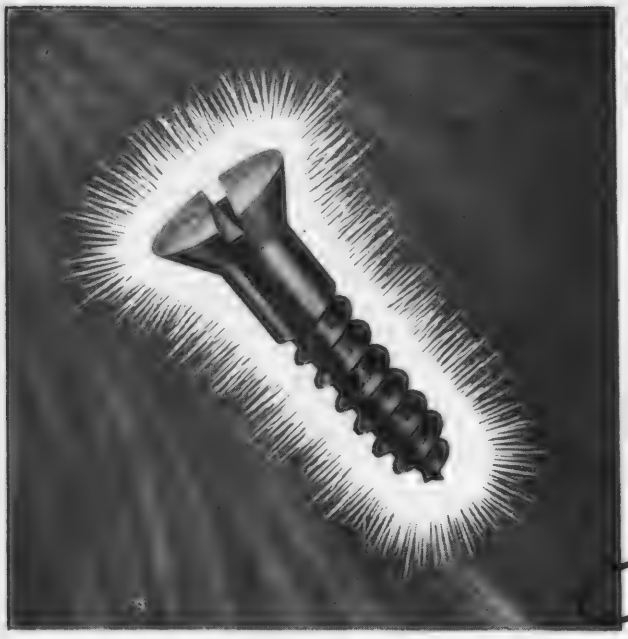

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It was voted that the chairman appoint a committee to draw up a simple set of by-laws for the consideration of the membership.

V. Annual Review

During the discussion it was suggested that all too often this review fails to uncover much new work, but is just a rehash of well-known material. It was pointed out that the Chemical Engineers list new processes in just one or two lines. It was reported by B. S. Bryant that someone had volunteered to review patents. Chairman Blomquist requested all members to send in new developments by October 1, in order to get them in the annual review. The following headings were suggested: glues; gluing equipment; test methods; new glued products; gluing technique; research technique; bibliography; and foreign developments.

The need for a manual or a book on glues and gluing with perhaps another manual on high-frequency gluing was discussed. It was also suggested that a list of unsolved problems of high priority be prepared.

VI. Officers and Committees for the Coming year.

Chairman: R. F. Blomquist, U. S. Forest Products Lab.; Vice-Chairman: B. S. Bryant, U. of Washington; Secretary: D. B. Richards, Alabama Polytechnic Institute.

Subcommittees and Chairmen:

I. Adhesives: R. F. Blomquist.
II. Gluing Techniques and Glued Products: Carl MacLagan and Curtis C. Booth.
III. Methods of Test: John Butler.
IV. Gluing Equipment: R. W. Williams.
V. Current Research: J. S. Bethel.
VI. Bibliography: B. S. Bryant.

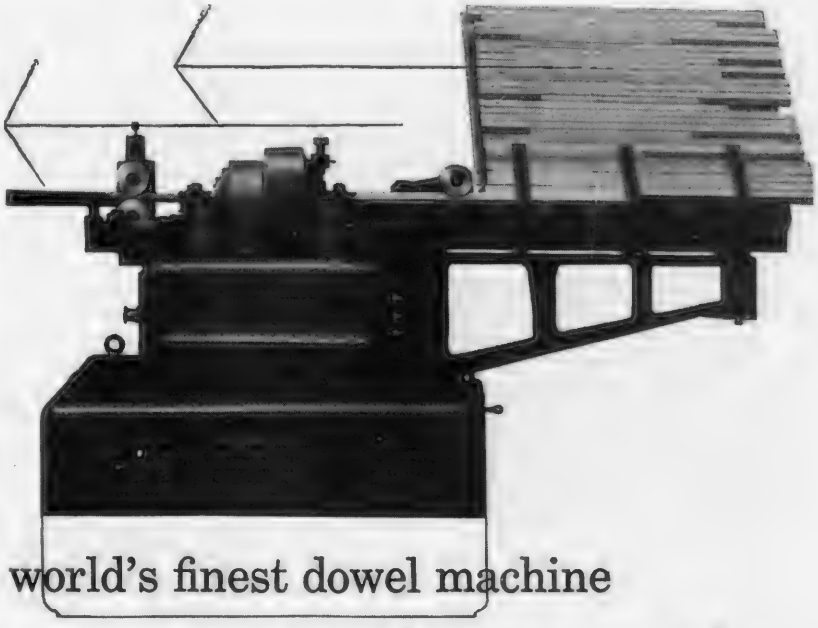
VII. Attendance:

Attending the meeting were: R. F. Blomquist, U. S. Forest Products Lab.; L. E. Clark, Jr., Perkins Glue Co.; B. S. Bryant, U. of Wash.; V. Marshall, Perkins Glue Co.; A. A. Marra, U. of Michigan; J. E. Marian, U. of Calif.; D. Brouse, U. S. Forest Products Lab.; R. H. Ripley, Douglas Fir Plywood Assoc.; M. L. Selbo, U. S. Forest Products Lab.; G. W. Lee, American Marietta Co.; J. S. Blanchard, American Marietta Co.; C. B. Hemming, U. S. Plywood Corp.; F. W. Herrick, Rayonier Inc.; R. J. Granger, Procter & Gamble; R. G. Batchellor, Wood–Mosaic Corp.; A. H. Bishop, State U. of N. Y. College of Forestry; O. B. Smith, William Cameron Co.; J. A. Klein, Reichhold Chemicals Inc.; T. E. Batey, Jr., Douglas Fir Plywood Assoc.; J. L. Butler, Reichhold Chemicals Inc.; I. F. Fleischer, Perkins Glue Co.; J. H. Syme, Edward Hines Lumber Co.; Maurice J. Rhude, Unit Structures, Inc.; H. E. Worth, Bureau of Ships; F. L. Brown, The Dow Chemical Co.; R. A. Moore, N. Y. College of Forestry; A. C. Barefoot, N. C. State College; M. H. Davis, Allied Chemical Corp.; J. E. Halberg, Hamilton Mfg. Co.; J. G. Rogers, Marion Plywood; J. K. Guiher, U. of Illinois; R. B. Bridges, Monsanto Canada Ltd.; P. H. McCormack, National Starch Products; C. C. Booth, Borden Chemical Co.; R. E. Gardner, Koppers Co. Inc.; G. B. Walker, Jr., Procter & Gamble Co.; R. C. Gill, Peter Cooper Corp.; K. W. Norwine, Pilliod Cabinet Co.; J. C. Meade, Catalin Corp. of America; R. E. Allen, National Casein Co.; B. H. Thielges, National Casein Co.; H. A. Vanduhoof, Bemidji Lumber and Mfg. Co.; R. L. White, Koppers Co., Inc.; L. Ropella, Roddis Plywood; D. B. Richards, Alabama Polytechnic Institute; A. J. Long, Monsanto Chemical Co.; T. McKenna, Monsanto Chemical Co.; W. A. Dobberfuhl, National Casein Co.

Career Booklet Progress Reviewed by Industry–Education Division

J. S. Bethel, Chairman, North Carolina State College, Raleigh, N. C.

Chairman Bethel opened the meeting with a discussion of the Career Opportunities booklet. Through the efforts of L. J. Carr and C. D. Dosker, NLMA has appropriated money to provide for publication of the booklet that was begun by Wangaard and turned over to NLMA. Chairman



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Bethel called on John Zerbe to report progress so far.

I. Report on Career Booklet.

John Zerbe reported that, after the approval of a career booklet, H. B. McKean and E. Butler worked on the manuscript, which was again reworked by the committee of NLMA that met in Santa Barbara. The booklet will be placed in the hands of high school students so that they can know what utilization or forest products engineering consists of. The title will be "Opportunities Unlimited".

NLMA expects to have a full-time staff educational consultant by September. This person will devote most of his time to publicizing this material, and will cooperate with universities in curriculum development. Mr. Zerbe reported that R. H. Berry is chairman of the NLMA Education Committee and H. B. McKean is a member.

Further discussion revealed that one booklet will be published for both students and vocational counselors and that possibly a folder for students will be published later.

II. 1959 Technical Session.

Chairman Bethel noted that the Division has had technical sessions every three years or so. The program for this year, he said, is entirely different from the one asked for last year by Nicholas Poletika. Perhaps, he said, next year we can carry out the original plan for this meeting.

The group voted to have a technical session in 1959 for which the responsibility would be placed on W. I. West as Chairman, assisted by N. V. Poletika and F. E. Dickinson.

III. Report on Formation of the American Institute for Wood Engineering.

Chairman Bethel reported that a constitution and by-laws were adopted at the National Meeting for this new organization. The constitution was accepted for a two-year period, at the end of which time it is to be reexamined, reaffirmed, modified, or replaced. The Institute will be closely affiliated with FPRS, and the Industry–Education Division is to act as a connecting link between FPRS and AIWE.

IV. Other Business.

Further discussion was held on means of attracting students into forest products technology. F. E. Dickinson reported on a program at the U. of California. Several years ago, a faculty member brought up the idea of bringing top science students in high schools to the campus to work on research projects under the direction of the faculty. Industries of the area contributed $2,200, about $500 each for four students. Letters were sent to science advisors in about 100 high schools in the area describing the program. Interested students filled out forms and submitted references. Students were considered on the basis of their interest. Projects submitted by faculty members were evaluated, and the names of acceptable students were given to those of the faculty who submitted approved projects. The faculty member then chose the student, and $500 was assigned to the project. Mr. Dickinson suggested that the idea be tried on a larger scale.

Mr. Ellis informed the group that the Great Lakes Section has organized a Committee for Education made up of members from the educational institutions and from industry. He suggested such a committee in each Section would be a good idea. The chairman was instructed to bring to the attention of the Section officers the desirability of having a Division member working with the Section. The meeting was then adjourned.

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LOGGING DIVISION

Bibliography of Logging Literature Ready for Preliminary Review

F. C. Simmons, Chairman, Northeastern Forest Experiment Station, Upper Darby, Pa.

The meeting was called to order at 10:00 a.m., June 26, 1958 at the Park Hotel, Madison, Wisconsin.

I. Administrative matters.

a. Election of Officers. Chairman Simmons stated that he felt it appropriate for the Division to elect a new Chairman in the near future. A brief discussion indicated that those in attendance felt Division Chairmen should hold that office for a three year period. The group voted that Simmons retain the chairmanship one more year.

Chairman Simmons announced that he would appoint a committee to nominate candidates for Division offices to be presented at the 1959 Annual Meeting. The same committee will be asked for a recommendation as to the tenure of these officers.

J. A. Doyle moved that Prof. R. F. Grah, U. of California, Berkeley, be appointed Vice Chairman during the current year. The motion was seconded and carried by unanimous vote.

b. Division Title. Chairman Simmons reported that during the annual meeting of Division Chairmen it was suggested that each Division consider changing its title from Subject Matter Division to Technical Division. The group unanimously voted to recommend to the Society Executive Board that the title of the Division be changed to Technical Division on Logging.

c. Additions to Division Technical Committee. The group agreed that selection of Technical Committee members should continue to be made on a geographic basis rather than by subject matter interest. Accordingly, Chairman Simmons appointed Robert W. Olin of Lewiston Idaho, David B. Turner of Port Alberni, British Columbia, and Yale Weinstein of Albuquerque, New Mexico, to represent the Committee in the Intermountain, Western Canada, and Southwestern regions, respectively. Chairman Simmons summarized the duties of the Division's Technical Committee as follows:

1) Represent the Division in their Section of the Society, and cooperate with other local organizations such as Loggers' Congresses and Technical Committees of the American Pulpwood Associations.

2) Answer inquiries to the Society concerning logging.

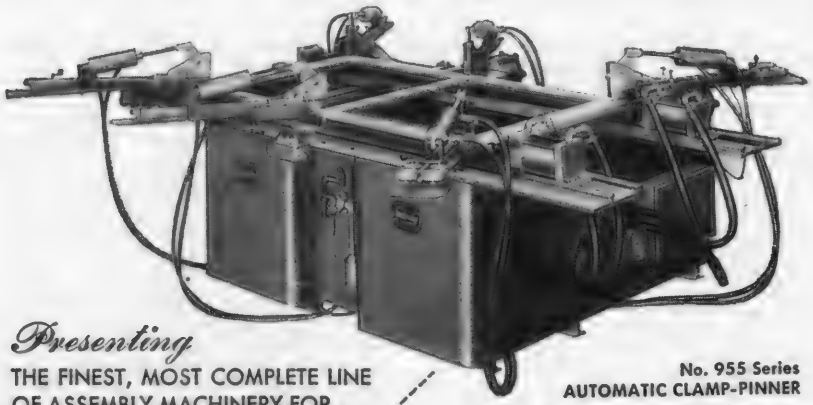
3) Prepare an annual report of developments in logging for publication in the FOREST PRODUCTS JOURNAL.

4) Develop a program for the Technical Session of the Society's Annual Meeting.

5) Review papers submitted for publication in the JOURNAL.

II. Projects.

At the 1957 Annual Meeting in Buffalo, the Division decided to prepare a classified bibliography of sig-



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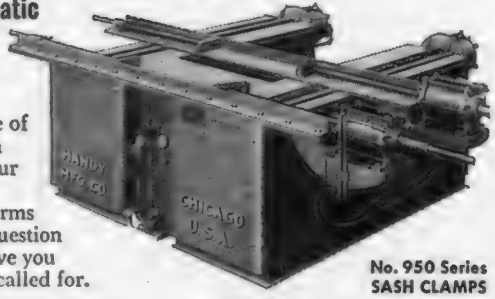

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nificant English literature on logging. Chairman Simmons distributed and asked for comments on a review edition of such a bibliography which he has compiled.

In the discussion that followed, Division members expressed the opinion that 1) such a bibliography would be valuable to educators, researchers, loggers, and others; 2) the Oxford system of Decimal Classification used in the review edition should be retained; and 3) the preface should be expanded to include references to other bibliographies of logging literature, including a bibliography of patents.

Chairman Simmons stated that he will distribute additional copies of the present edition for technical review.

III. Technical Session for the 1959 Meeting.

The group discussed possible themes for the 1959 session. It was decided that the Program Committee should be instructed to seek papers covering a broad field rather than attempt to develop a single theme.

The meeting was adjourned.

IV. Attendance.

Those attending the meeting were: F. C. Simmons, Northeastern Forest Experiment Station; R. A. Anderson, Iowa State College; James R. Clark, Soderhamn Machine Mfg. Co.; Richard Connor, The Connor Lumber and Land Co.; V. W. Cothren, Southern Pine Assoc.; J. A. Doyle, Ottawa Forest Products Lab.; Emanuel Fritz, Foundation for American Resource Management; Walter Giles, Canadian Dept. of Lands and Forests; Walter M. Henze, Consulting Forester; David E. Herrick, Carbondale Forest Research Center; John W. Lehman, Tennessee Valley Authority; S. W. Loiry, Soderhamn Machine Mfg. Co.; Milton H. Mater, Mater Engineering; Robert W. Olin, Potlatch Forests, Inc.; Lionel Pease, Mill Equipment, Inc.; Don M. Post, U. of Florida; David B. Turner, MacMillan and Bloedel Ltd.; Walter W. Warner, S. M. Builder Co.; Yale Weinstein, New Mexico Timber Co.; Herbert I. Winer, Yale Forestry School; John W. Young, Rochester, N. Y.

Field Research Questionnaire Completed by Lumber Manufacturing Division

Clearing House Committee to Disseminate Results

Milton H. Mater, Chairman, Mater Engineering, Corvallis, Ore.

The meeting was called to order by Chairman Mater. H. I. Winer was appointed temporary recording secretary. The minutes of the 1957 meeting of the Division at Buffalo were read and accepted.

Chairman Mater reported on the monthly machinery and mechanical improvement questionnaire, designed to promote knowledge of current developments in sawmilling. The project may lead to a monthly column of information in the FOREST PRODUCTS JOURNAL, Mater said.

I. Report on Field Research Questionnaire.

Norman C. Bye gave this report. Fifty seven replies were received from about 175 recipients of the questionnaire. Mr. Bye's subcommittee sorted out the areas of research interest and prepared a preliminary unabridged list of suggestions, copies of which were distributed. The subcommittee intends to 1) distribute the preliminary list of suggested projects to all those who replied to the questionnaire; 2) condense and reclassify the preliminary list into workable categories for use by the Research Clearing House subcommittee; and 3) continue to solicit research questions so that the list may be kept up to date.

Chairman Mater expressed the thanks of the Division to Mr. Bye and Mr. Compton for their continuing efforts in the questionnaire project. He then designated David E. Herrick as chairman of the Research Clearing House subcommittee. The functions of the subcommittee will be to:

1. Distribute tentatively abridged research lists to research institutions of all types; 2) determine which projects are being worked on; 3) circulate all relevant information about work in progress to members and cooperators,

The Lumber Manufacturing Division discussed dissemination of the results from the Research Questionnaire on Sawmilling

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becoming a clearing house for research information in sawmilling; and 4) emphasize in all these activities the importance of contacts with foreign workers and organizations in the field of sawmilling research.

II. Division Reorganization.

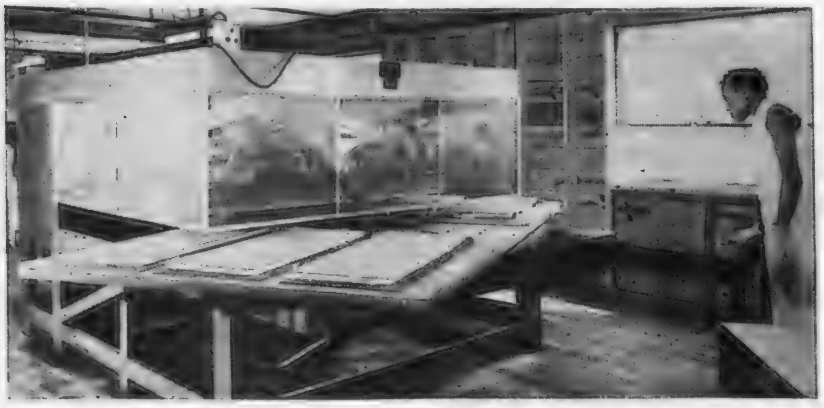
Chairman Mater proposed revising and strengthening of the Division by redesignating the Steering Committee as the Division Technical Committee, with officers including a chairman, vice-chairman, and secretary. The Committee would operate through its permanent subcommittees, including those concerned with: Field Research Questionnaire; Research Clearing House; Log Handling at the Mill; Log Breakdown Within the Mill; Quality Control, Grading, and Standardization; and Lumber Handling. The reorganization proposal was adopted by the group. Chairman Mater reported that no action had yet been taken on a motion adopted at the Buffalo meeting in 1957 to study the best method of measuring lumber for quality control purposes.

III. New Officers.

Milton H. Mater was nominated to serve another year as chairman. He was re-elected by acclamation. Herbert I. Winer was elected to the position of Division Secretary. The post of vice-chairman remained vacant. The meeting was adjourned.

IV. Attendance.

Those attending the meeting were: Norman C. Bye, Disston Div., H. K. Porter Co.; James R. Clark, Soderhamn Machine Mfg. Co.; Richard M. Connor, Connor Lumber & Land Co.; Virgil M. Cothren, Southern Pine Assoc.; J. A. Doyle, Ottawa Forest Products Lab.; Hereford Garland, Michigan College of Mining & Technology; Nels G. Glesne, Casswood Industries, Inc.; David E. Herrick, Carbondale Research Center; John W. Lehman, Tennessee Valley Authority; S. W. Loiry, Soderhamn Machine Mfg. Co.; James L. Lubkin, American Machine & Foundry Co.; John K. Martin, W. H. Rambo; Jean Mater, Mater Engineering; Milton H. Mater, Mater Engineering; R. W. Olin, Potlatch Forests Inc.; Lionel Pease, Mill Equipment Inc.; Don M. Post, U. of Florida; J. R. Ritchie, Wm. Milne Sons, Ltd.; E. Chat Shanks, E. Chat Shanks; Fred Simmons, Northeastern Forest Experiment Station; Walter W. Warner, Ontanogan; A. W. Toole, Lake States Forest Exp. Sta.; Yale Weinstein, New Mexico Timber Co.; H. I. Winer, Yale Forestry School; J. W. Young, Rochester, Minn., J. I. Zerbe, NLMA.



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Professor Lloyd Appointed Chairman of Merchandising Division

R. D. Pauley, Chairman, Weyerhaeuser Timber Co., Tacoma, Wash.

In the absence of Chairman R. D. Pauley and Vice-chairman George E. Olson, J. J. Allegretti opened the meeting of the Division at 8:30 a.m. on July 25, 1958 at Madison, Wisconsin.

The first item on the agenda was a discussion relative to the desirability of having a Merchandising Technical Session at the next Annual Meeting in San Francisco. The group unanimously voted to hold such a session.

William B. Lloyd, Associate Professor of Forest Products, Michigan State University, East Lansing, was designated Chairman for the coming year. Mr. Lloyd stated that he would try to arrange an interesting program of papers for next year's Annual Meeting, and that he would try to direct more attention towards the Merchandising Division.

Packaging Division to Reorganize During 1958–59

A. R. Tegge, Chairman, Quartermaster Food and Container, Inst., Chicago, Ill.

I. 1958 National Meeting program.

Although the Packaging Division did not offer a separate technical session at the 12th Annual Meeting, packaging topics were included in the program. Cooperation of the Wood Preservation Division and Lumber Manufacturing Division chairmen made it possible to present papers on treated wood ammunition boxes and unitized lumber at their respective sessions.

Mr. Tegge noted that plans are being made for a technical session on packaging at the 13th Annual Meeting of the Society in San Francisco.

Annual Review Themes Discussed by Veneer and Plywood Division

J. L. Butler, Chairman, Reichhold Chemicals Inc., Charlotte, N. C.,

The meeting was called to order by Chairman Butler. John Lutz acted as recorder. The minutes of the 1957 meeting were read and unanimously accepted by the membership.

I. Annual Report.

Chairman Butler opened the discussion by observing that the Annual Reports often contain little new material and are a rehash of developments reported elsewhere. Dr. Bethel suggested the possibility of dividing the review into different fields. One year the review could discuss raw materials such as veneer yield by log grades. The fol-

MERCHANDISING DIVISION

QUALITY CONTROL DIVISION

lowing year might be devoted to material handling, the next year to machinery, and so forth.

Dr. Alan Marra and Prof. Leney requested that the report be continued on an annual basis covering the outstanding developments of the year.

Chairman Butler stated that he preferred to have the Annual Report limited to developments that are current. He requested that members forward information they might have to him at 2370 Leafmore Drive, Decatur, Ga.

II. 1959 National Meeting.

The group voted unanimously to hold a technical session at the San Francisco meeting. Chairman Butler reported that the keynote of the 1959 meeting will deal with the economic gain that can be made from research.

Topics for papers that were suggested were: Marketing aspects of plywood made from West Coast hardwoods, the influence of log grades on processing costs, and the differences between typical hardwood and softwood plywood plants.

At the request of Chairman Butler, Prof. Lawrence Leney described some work he is doing on a fundamental study of veneer cutting.

Members who have knowledge of qualified speakers or topics for the meeting were requested to forward this information to John Lutz, U. S. Forest Products Laboratory, Madison 5, Wis.

III. Attendance.

Those who attended the meeting were: Lawrence Leney, U. of Missouri; J. S. Bethel, N. C. State College; R. W. Wellwood, U. of British Columbia; R. G. Batchellor, Wood–Mosaic Corp., D. B. Winchester, Poinsett Lumber and Mfgr. Co.; F. L. Brown, The Dow Chemical Co.; Alan Sliker, Mich. State U.; R. A. Moore, N. Y. State College of Forestry; J. R. Ash, Monsanto Chemical Co.; T. McKenna, Monsanto Chemical Co.; A. J. Long, Monsanto Chemical Co.; J. R. Roberts, The Celotex Corp.; A. Locher, United Wood Corp.; W. A. Henze, Consulting Forester; Armin Elmendorf, Elmendorf Research Inc.; A. A. Marra, U. of Michigan; Don Brouse, U. S. Forest Products Laboratory; J. A. Klein, Reichhold Chemicals, Inc.; R. H. Ripley, Douglas Fir Plywood Assn.; T. E. Batey, Jr., Douglas Fir Plywood Assn.; John Butler, Reichhold Chemicals Inc.; and John Lutz, U. S. Forest Products Laboratory.

Wood Composition Board Division Holds Lengthy Discussion of 1959 Program Plans

James R. Roberts, Chairman, The Celotex Corp., Des Plaines, Ill.

Chairman Roberts opened the meeting by stating that the steering committee would like a discussion of the effectiveness of the program as developed for the 1958 meeting. The committee was interested in knowing if it was what the members wanted, if it was effective, what should be done at future meetings as far as a program was concerned, and what subjects should be covered.

I. Discussion of Technical Session Forms and Content.

During the discussion it was pointed out that the exchange of pro's and con's during the discussion period was more important than the previously prepared introductions. It was suggested that the opening introductions be eliminated in the panel discussions.

Dr. George Marra pointed out that the lack of an effective microphone for speakers from the audience seriously hampered participation. Chairman Roberts felt that more discussion on sales problems was needed.

It was emphasized that questions for a discussion panel should be examined before the meeting, and those requiring an evasive answer or a divulgence of "know-how" classified as a trade secret be culled.

The group voted to hold a discussion-type panel at the next annual meeting. It was suggested that questions be published in the JOURNAL prior to the meeting to stimulate thinking ahead of the session proper. Mr. Noble said he felt greater emphasis should be placed on customer wants and needs, rather than what industry makes and wants the user to adopt.

VENEER AND PLYWOOD DIVISION

WOOD COMPOSITION BOARD DIVISION

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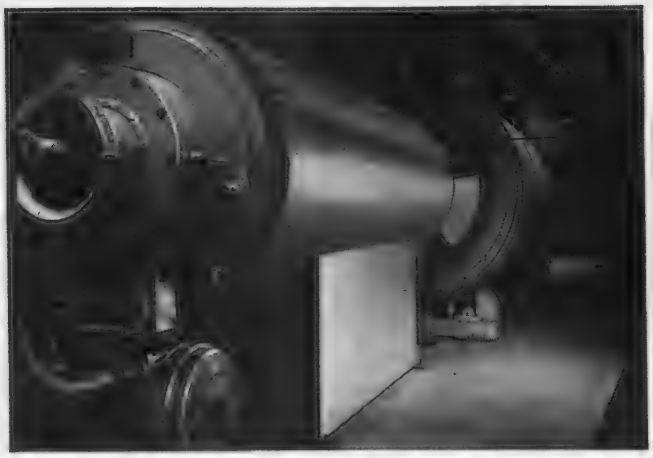

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WOOD DRYING DIVISION

WOOD FINISHING DIVISION

It was stated that eastern members of the Society should be requested to present papers at the next meeting. Mr. Koellisch suggested that one session should deal with problems of interest to producers and one with problems of users. During the discussion, substantial interest was shown in discussing sales and markets.

Mr. L. A. Patronsky suggested that next year the Division not present any papers that deal with older devolopments. The group voted to hold two sessions and a Division meeting at the 1959 National Meeting.

II. Standards.

Mr. Patronsky reported that the Association of Particle Board Producers was trying to develop standards along with many other things vital to an industry. He felt that a profound discussion on standards and what standards should cover would be beneficial. Mr. Dale Turner stated that a good deal of values in standards are entirely useless to the customer.

The meeting was adjourned at 12:00 noon.

Sponsorship of Technical Motion Picture Being Investigated by Wood Drying Division

Stephen B. Preston, Chairman, University of Michigan, Ann Arbor, Mich.

I. Report on the Division's NEWS-DIGEST.

Continued success of the Division's NEWS-DIGEST was described by R. C. Rietz. The digest is a 2-page condensation of a published article or talk in the field of seasoning. Subjects include practical matters in applying established procedures, results of applied research by kiln club members, and explanations of more advanced research. The Digest is issued monthly and 2,500 copies are distributed through 21 wood drying organizations.

Mr. Rietz requested additional papers on the drying of wood for inclusion in the Digest series and offered to distribute copies to additional members through existing clubs or new groups.

II. Report on Conference on Fundamental Research in Drying of Wood.

R. L. Youngs summarized the conference that was held Oct., 1957 at the Forest Products Laboratory in Madison. Forty persons engaged in drying of wood and other agricultural products participated. It was agreed that present fundamental knowledge of wood drying is inadequate and more basic research is needed. It was recommended that the following fields be given top priority in future drying research.

1. Anatomical structures affecting the permeability of wood. 2. Mechanisms influencing the moving, or holding, of water in wood. 3. Determinations of the stress-strain relationships within wood. 4. Stress-strain failures as related to drying conditions, time, and micro-structure of wood. 5. Transfer of heat and mass during drying. 6. Chemical methods of drying. 7. Use of unconventional sources of energy.

Discussion at the conference revealed the opinion that basic drying principles are similar for many agricultural crops and products, and that wood drying researchers should keep informed of new developments in these related fields that might be applicable to the drying of wood. Improved kiln techniques and methods must also continue to be developed.

III. Technical Movie on Wood Drying.

Harold Gatslick, N. Y. College of Forestry, proposed that the Wood-Drying Division sponsor preparation of a technical movie on wood drying. He showed a short color film made by Dr. W. M. Harlow on the shrinkage of wood using time-lapse photography technique. For comparison, a German film on shrinkage using the animated-diagram technique was also shown.

Dr. Gatslick stated that the College of Forestry at Syracuse was equipped to make a time-lapse movie of the entire sequence of drying wood. A 22-minute film would require about two years to make and cost about $10,000. He pointed out the film would be helpful in teaching wood technology. Other uses, such as for dry kiln club meetings and management conferences, were brought out in the discussion. Prints would cost $30 for black and white, $64 for colored, and nominal rental fees could be charged for single use.

Ways and means of financing the film were discussed. Three possibilities were: 1) direct support by dry kiln clubs and seasoning associations; 2) subscriptions from firms in the lumber producing, wood drying, and woodworking fields; and 3) a grant from an educational or research foundation.

The Division voted to accept the production of a technical film on wood drying as a project and to set up a subcommittee for this purpose with Dr. Gatslick as chairman.

IV. 1959 Technical Program.

The Division plans to have a Technical session at the 1959 annual meeting and discussed the possibility of a joint technical session with the Lumber Manufacturing Division.

Forty-seven members and other interested persons attended the meeting. The meeting was then adjourned.

Wood Finishing Division Plans 2 Sessions at 1959 Meeting

F. H. Thomas, Chairman, Sherwin-Williams Co., Chicago, Ill.

The meeting was called to order at the U. S. Forest Products Laboratory on Wednesday morning, June 25, by Chairman Thomas.

I. New Officers.

The group voted that D. G. Lubeck and D. F. Laughnan be recommended for approval to the Executive Board as

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Chairman and Vice-Chairman, respectively, of the Wood Finishing Division.

The members of the Division expressed their appreciation for the fine job that Mr. Thomas did during his tenure in office. It was felt that his efforts had strengthened the Division and produced one of the finest sessions (1958) that the Division has held.

II. Reorganization.

The group expressed the thought that the membership should be divided into sub-groups. Sub-committees contemplated for the future are: education; interior finishing materials; exterior finishing materials; processing equipment and techniques; testing methods; and foreign developments.

III. 1959 Program.

The group voted to hold two sessions at the 1959 meeting in San Francisco. It was proposed that the sessions be conducted as panels, with each speaker giving a brief introduction to the subject and then allowing questions from the floor. The two sessions suggested and their possible topics are:

New Processing Methods

Sanding; catalized spraying; airless spraying; flow coating; electrostatic spraying; steam spraying; dipping; tumbling; and roll coating.

New Finishing Materials

Polyesters; Polyurethane; exterior clears; epoxy solutions; and exterior emulsion.

IV. Attendance.

Those attending the meeting were: F. H. Thomas, Sherwin-Williams Co.; D. G. Lubeck, Hammond Organ Co.; W. I. Kyle, DuPont; H. C. Fornwall, DeVilbiss; Paul E. Leary, Wolverine Finishes Corp.; L. A. Martin, 3M Co.; A. W. Gilliam, Sherwin-Williams; Paul A. Rush, Sherwin-Williams Co.; Orville H. Lerch, Sherwin-Williams Co.; Joseph P. Urbanek, Q. M. Res. & Dev. Center; Chas. B. Baker, Sherwin-Williams Co.; A. E. Bogan, Fed. Prison Industries; J. G. McGill, American Cyanamid; D. F. Laughnan, U. S. Forest Products Lab.; Glenn P. Bruneau, U. of Michigan; George J. Meyers, Roddis Plywood Corp.; R. L. Campbell, Wilco Machine Works; Alex Andreoni, The Glidden Co.; R. E. Boddorff, Hercules Powder Co.; Kurt G. Sense, Behr-Manning; Harvey Bennett, Behr-Manning; Robert S. Taub, Sherwin-Williams; E. J. Saba, Sherwin-Williams; R. M. Carter, N. C. State College; H. G. Larrick, Sr., Solana Cedar & Milling Co.; W. J. McClements, Carr, Adams & Collier Co.

Fire Retardant Treatments to be Topic at 1959 Wood Preservation Session

C. S. Walters, Chairman, University of Illinois, Urbana, Ill.

I. 1959 Technical Session.

The group voted to hold a half-day session at the 1959 meeting at San Francisco. In general it was agreed that papers presented next year should be fewer and shorter to allow more time for discussion. No more than four papers should be presented, and the authors should be held to schedule. "New developments" should be worked into the program. Possible topics suggested were:

1. Limitations imposed by building codes on use of wood structural components. 2. The comparison of insurance rates on wood structures with those on structures built of noncombustible materials. Why do wood structures carry such a high rate? What is the basis for classifying all wood (treated and untreated) in the same category?

3. A panel discussion was suggested as one means of presenting information on wood treated with fire retardants. 4. New developments in the use of treated wood structural components in buildings. 5. Any new developments in use of fire-retardant treated wood in marine structures.

6. The use of fire-retardant treatments for board materials (insulating, hardboard, particle board, plywood). 7. A report on inspection data collected by pest-control operators and filed with one of the California state agencies. These reports are required by the State of California on condition of each house inspected by a pest-control operator, including condition of house with respect to decay and insect attack.

Other topics suggested for future meetings were: increasing the markets for wood in building construction through treatment, and the possibilities of using treated wood in furniture, particularly for outdoor types.

II. New Officers.

The group voted that C. S. Walters and A. H. Bishop be recommended to the Executive Board for approval as chairman and vice-chairman for 1959.

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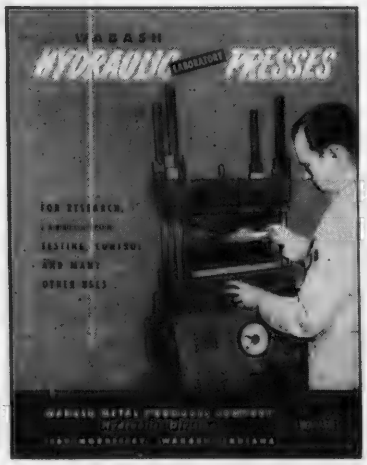

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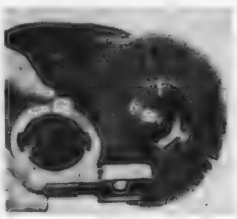

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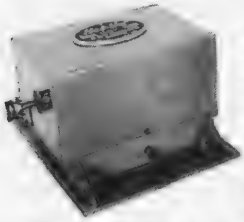

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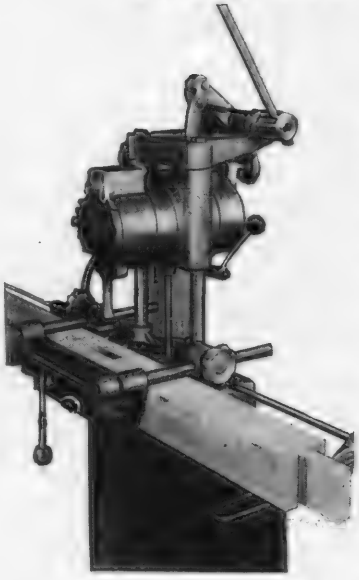

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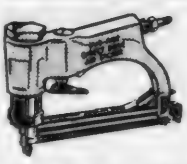

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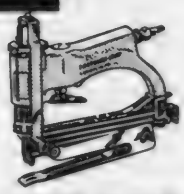

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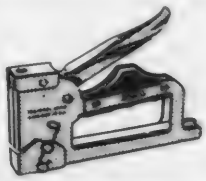

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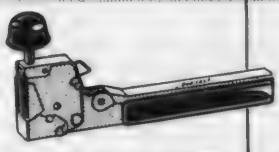

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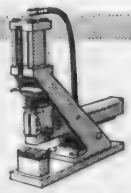

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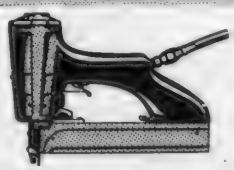

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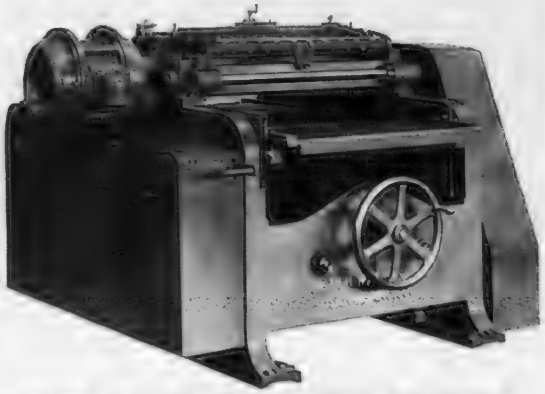

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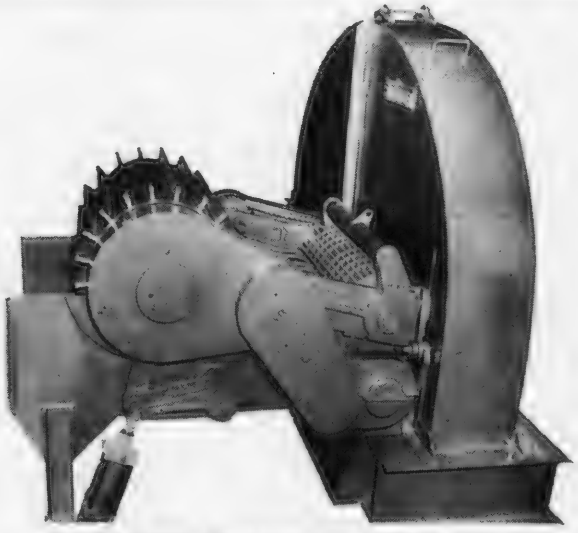

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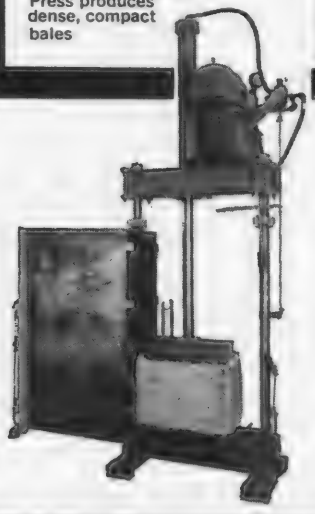

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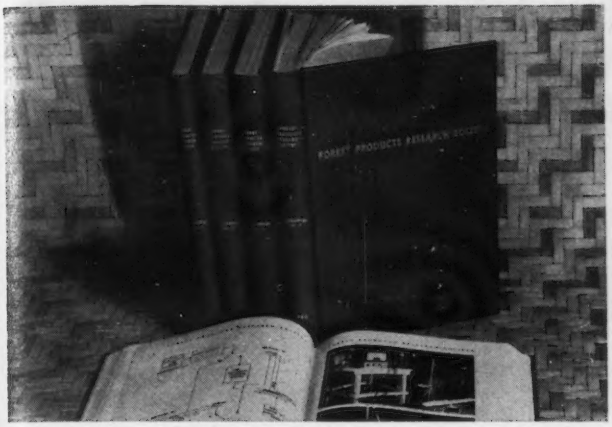

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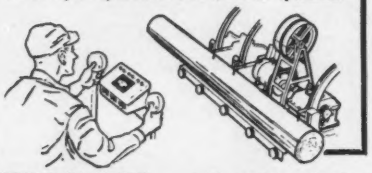

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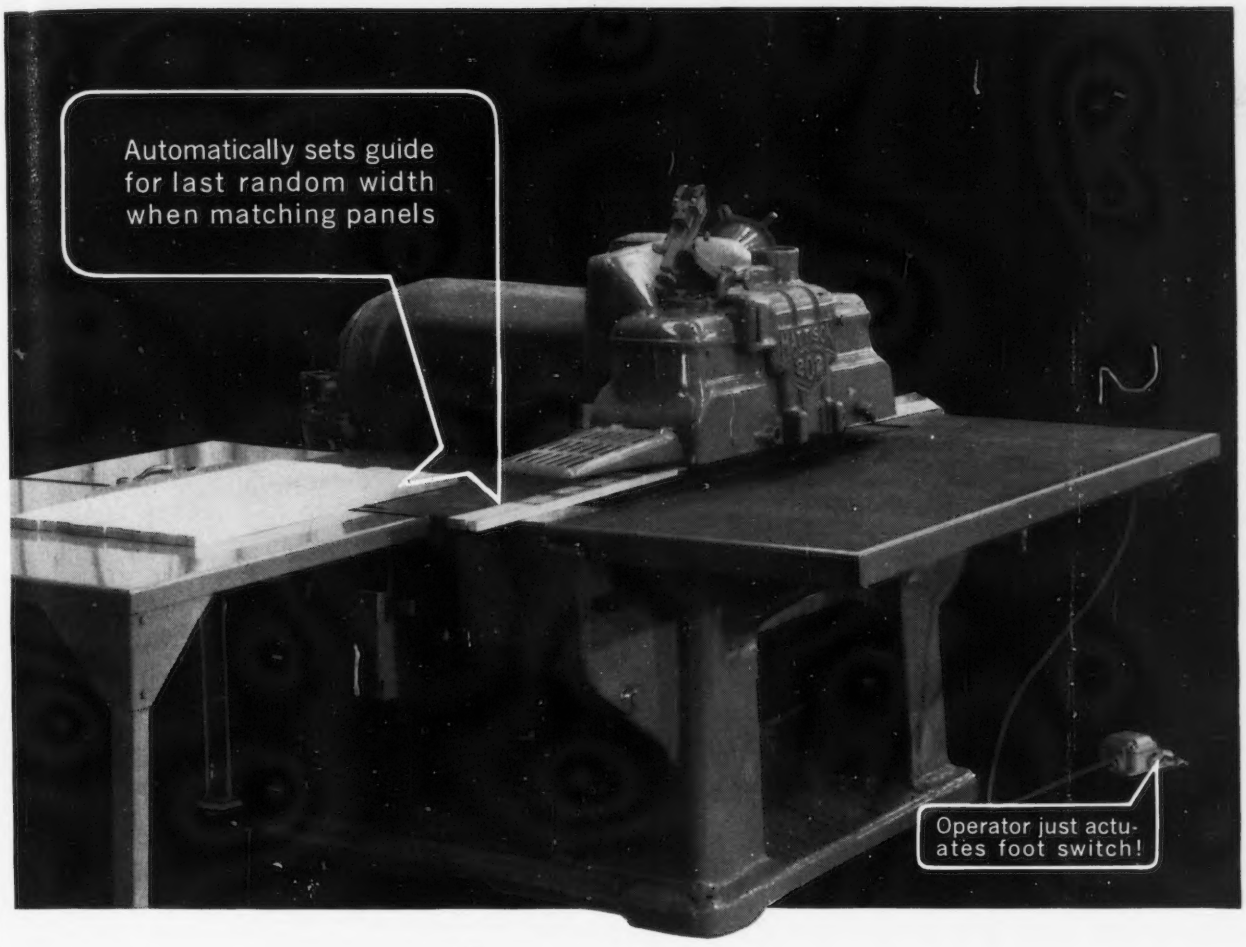

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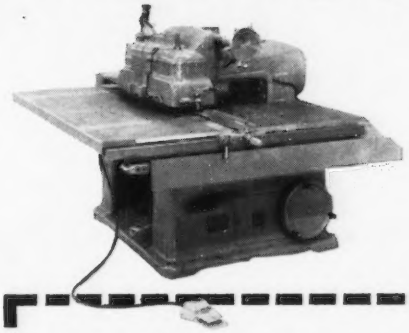

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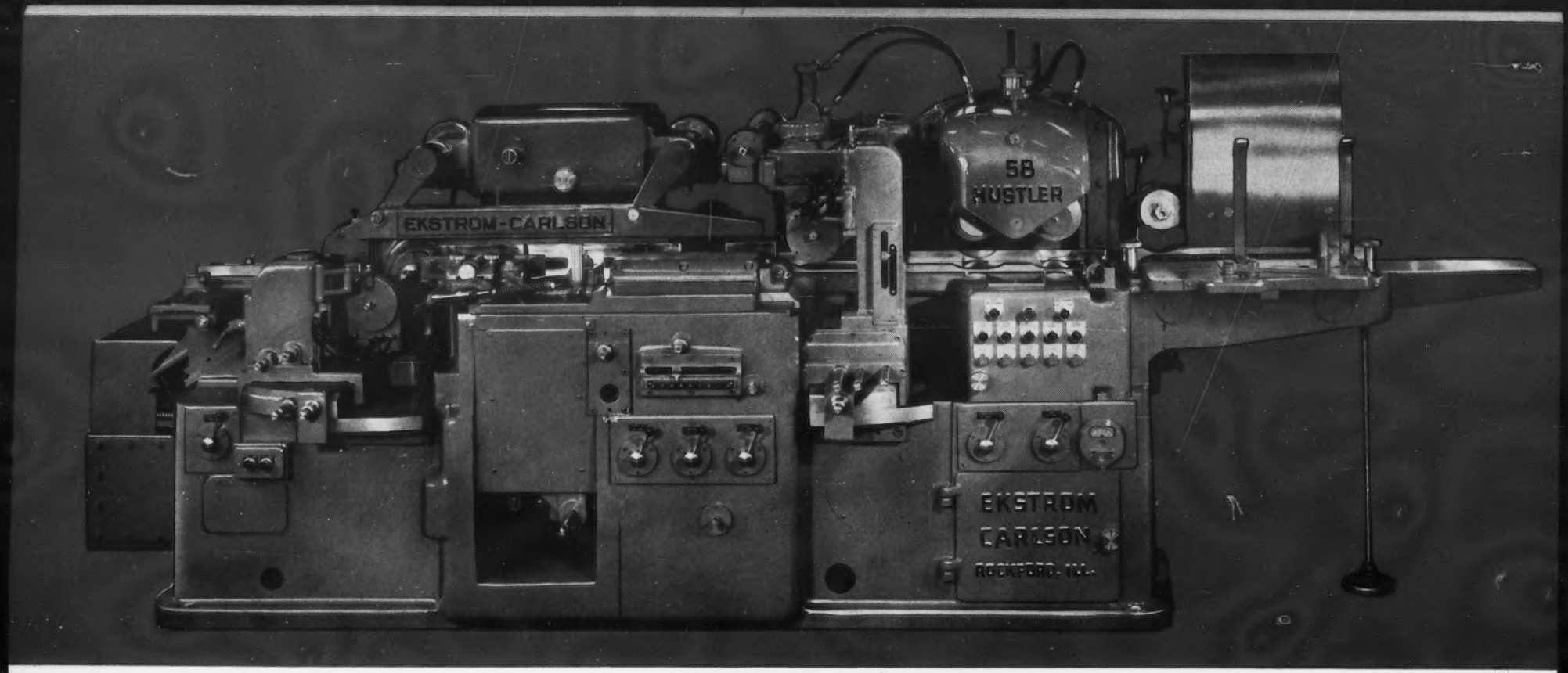

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